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Thomason Civil Engineering College, Roorkee.

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PROFESSIONAL PAPERS

ON

INDIAN ENGINEERING.

FEBRUARY, 1864.

EDITED BY
MAJOR J. G. MEDLEY, R. E., A. I. C. E.,
PRINCIPAL, THOMASON COLLEGE, ROORKEE.

ROORKEE:
PRINTED AT THE THOMASON CIVIL ENGINEERING COLLEGE PRESS.
MDCCCLXIV.

PREFACE TO No. II.

I HAVE to acknowledge with thanks the receipt of several valuable papers from the P. W. Secretariats of the N. W. Provinces and the Punjab, and the promise of others from Bengal and Mysore. I shall hope to be favored with similar assistance from the Governments of Madras and Bombay, British Burmah, Oudh, &c., in future numbers.

I beg also to thank the Military Department for permission to publish the last G. T. Survey Report, and shall be glad to be allowed to produce some more of the many valuable Survey Records which are probably available in the Surveyor General's and the G. T. Survey Offices.

No. III. will appear on the 1st May, and will, I hope, contain some interesting details of works on the Punjab Railway.

The price to subscribers will be for the present year 3 rupees per number, or 14 rupees for the first five numbers, forming the first volume, (*i. e.* to the end of the current year,) payable in advance to the Editor at Roorkee; or to Messrs. Thacker and Co., Calcutta; Messrs. Pharoah and Co., Madras; Messrs. Thacker and Co., Bombay; or Messrs. Grindlay and Co., Parliament Street, London.

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J. G. M.

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ERRATA IN No. I.

In Paper No. V., on Irrigation and Drainage in the Deyrah Dhoon, an error occurred in the manuscript which I am sorry I overlooked in preparing it for the Press. At page 60, the length of the Dhakia Bund is given as 12,000 instead of 1,200 feet; and at page 61, the cubical contents of the tank thus formed, are given as 4,80,00,000 instead of 48,00,000 as they ought to be. Colonel Baird Smith's calculation will therefore be 20,000 (not 2,00,000) cubic feet of water for one beegah, which will still be *six* times more than the quantity allowed by Colonel Cautley. The argument remains the same.

Page 99, line 12, *for* 'renown' *read* 'crown.'

SOME REMARKS ON THE LATE SANITARY COMMISSION.

SERIOUS as are the evils brought to light in the Report of the Commission appointed to enquire into the Sanitary state of the British army in India, it is consolatory to remember that much has been done of late years to remedy those evils, and that much of what is complained of belongs already to the past. The enquiries of the Commission extended back through the last fifty years; the laws of Sanitary science have scarcely been enunciated for fifteen, that is to say, since the outbreak of Cholera in England in 1848, a date contemporary with our occupation of the Punjab and the construction of a large number of new Stations and Barracks. Undoubtedly, in some cases, mistakes were made in choosing and erecting these, but much care was employed in the selection of the sites,* and the comfort and health of the soldier carefully studied in designing the plans. Sites were chosen by just such a Committee as is recommended in the Report of the Commission—the Civil, Military, Medical, and Engineering interests having been always represented. Those who have seen the barracks at Sealkote, Mean Meer, or Rawul Pindee, with their wards 24 feet high in the clear, and their double verandahs, exclusive of which an allowance of 1000 cubic feet or 64 superficial feet, per man, has been made in point of space, will not consider that the soldiers are rendered unhealthy by over-crowding. Indeed the cost to Government for housing the troops at those stations was not less than 1,200 to 1,500 rupees per man, rather more than the cost to each officer of housing himself.

---

* A remark may here be made as to the choice of Cantonment sites. The ugliest and most barren spots have as a rule been selected. This has no doubt partially risen from a disinclination to occupy cultivated land, but it seems also to have been due to a vague idea that trees and vegetation in general were unwholesome. Granting that rank vegetation, such as close underwood or dense jungle, shows generally that a site is unsuitable for building, yet on the other hand, it may be taken as a safe general rule that the presence of healthy vegetation, such as trees, wheat-crops, &c., as distinctly mark the healthiness of a place. From a neglect of this consideration it arises that having selected such a site as Mean Meer for instance, a barren plain absolutely devoid of vegetation, trees cannot be induced to grow, and the place seems as likely to be unfavorable to human as it is to vegetable life.

The intermittent fevers so prevalent in the Punjab, used at first to be invariably attributed by medical men to the influence of 'stagnant water' or 'decayed vegetation,' and the example of Peshawur was always adduced in proof. Yet in the year 1851, six hundred men of one regiment alone then at Mean Meer, were floored by this fever.

Bearing in mind this large expenditure, it is not at all clear that the best form of barrack has been hit upon so as to secure the maximum of comfort as well as health, to the occupants. Lofty and well ventilated as the Punjab barracks are, they are very cold and cheerless in the cold weather, while in May and June it is almost impossible to exclude the hot winds or cool the huge wards artificially. The half company barracks at Nowshera, in which each ward forms a separate room for twelve men, are the most comfortable I have yet seen, and it is understood that the present Public Works Secretary in the Punjab, has proposed to carry out this plan still further by building a series of detached buildings to hold a few men each, in lieu of the present large barracks for a number. Although, at first sight, it would seem a more expensive plan, as demanding the same amount of roofing and flooring surface with a greater number of walls, yet on the other hand less lofty and substantial walls would be required for smaller buildings, so that the difference in cost would probably not be great. The advantages claimed are, that the soldiers would have a more home-like feeling about such buildings, and with the greater privacy secured, they would gain more self respect, while under

Bahadoor Khail, on the Trans-Indus frontier, another barren spot, is continually scourged by the same disease. This form of fever as a rule seems most prevalent in places close under the hills, and Captain Dyas, R.E., suggested some years ago that stagnant *air* caused by the proximity of the hills had probably more to do with it than stagnant water.

proper supervision there is no reason that discipline should suffer by the change.

It is often forgotten that we cannot locate our troops where we like in India, and that though no doubt it would be very desirable to have them all quartered in the healthiest places, yet the proper military occupation of the country is the first point to be considered, and thus the choice of a site for a cantonment is generally very narrow. Thus was Barrackpore originally fixed upon to watch the Danish Serampore; Berhampore to over-awe Moorshedabad; Dinapore to look after Patna; Cawnpore to watch Oudh, and so on. When the several lines of railways are completed throughout the country, much of this may be changed and our troops concentrated in healthy places, but even then people judging in England are apt to forget our immense distances, and in case of a popular insurrrection, a railway is very easily disarranged.

What has been said above as to the proximity of large towns to cantonments, points at once to a chief cause of the unhealthiness of the latter, and to the remedy to be applied, both of which are pointed out in the Report. A densely crowded native city with narrow unpaved streets, and an utter absence of all drainage or sanitary arrangements, must be such a hot-bed of disease that we surely cannot have far to seek for the cause of cholera. Much has been done within the last few years, but much more remains to be done in this direction. Many of the larger native cities have been paved, partially drained, and conservancy arrangements initiated, but no one can go through the smaller towns and villages, where no European authority is present on the spot, without seeing how much reform is needed. As these improvements are carried out by local funds it is no doubt easiest to raise the necessary funds in the great towns than in the small ones, but even these could in most cases be very much improved at a trifling expense, and every town or village not so improved is a public nuisance dangerous to others besides itself, and should be treated accordingly.

Drainage is not generally a difficult matter, most towns and villages, in the Upper Provinces at least, being built upon elevated spots. If old walls, ruined or half built houses (which become mere receptacles of filth) were pulled down, dung heaps removed, and no new houses allowed except on some uniform plan, much would be done at a very trifling cost. The paving and drainage of the streets is a more serious matter, but is after all not expensive, and the measure is imperative. It is hopeless to expect to carry the uneducated people with us generally on these points, looking as they do upon disease as a fatality, and not as a preventible evil, but we had and still have the same difficulty in England, and the Hindoo is certainly more cleanly than the English laborer. It is just one of those cases where the people should be coerced not merely for their own good but for that of all around them.

The best method of conservancy for towns or cantonments is still an open question. In large cities, such as Calcutta, where there is money to pay for an elaborate system of covered drains and sewage, we have European experience to guide us. But few native towns could afford to pay for such a scheme, even if there were always a natural receptacle at hand for the discharge of such sewage; while in cantonments it would obviously be impracticable. The system of cess-pits is now strongly condemned, and the dry-conservancy method, as it is generally termed, whereby night soil and refuse is carried bodily away and deposited in the earth, is pretty generally advocated. Still this, though applicable to a cantonment, would not do in a town of any size, and the whole subject is one demanding serious attention.

Another point touched upon by the Commission is the question of water supply. Troops are generally supplied from wells, and the drinking water as a rule is excellent; moreover, in the new cantonments a plunge bath is provided, in addition to the regular wash-houses or bath rooms in the barracks. What is still wanted, however, is a large bath for each barrack, with a good supply of water always laid on. The attention of Government is directed it is believed to this point, and the experiment of wells sunk to such a depth as to afford a practically inexhaustible supply having been tried successfully at Allahabad, will be probably sanctioned for other stations. The expense is doubtless considerable, varying probably from 2 to 5000 rupees per well, and the cost of lifting the water will be much heavier; the Persian wheel would not be applicable, and pumps worked by steam or bullock power would be necessary. The question of water-supply for native towns is one of much importance and difficulty, and the religious and caste prejudices of the people throw obstacles in the way of affording anything like a common and constant supply. But the influence of the authorities should be peremptorily exercised to effect at least the clearance of tanks and their preservation from pollution; while the water for drinking might be separated from that used for other purposes, and where necessary, filtered* into a small reservoir.

With the remarks made by the Commission on the dieting of

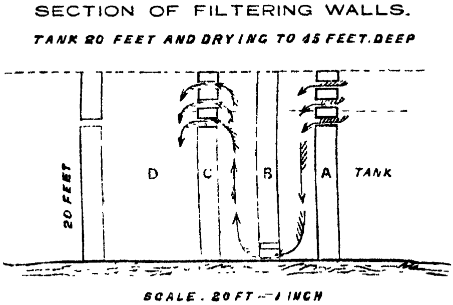
---

* The following description of a cheap and simple filter proposed for native tanks is extracted from the Asiatic Society's Journal for 1852:—

A is a wall enclosing any space with openings of any kind *at the top only*.

B a second wall with small arched openings *b* below.

C is a third wall with openings only at the top again discharging into the reservoir D for the clean water.


SECTION OF FILTERING WALLS.
TANK 20 FEET AND DRYING TO 45 FEET.DEEP
20 FEET
D
C
B
A
TANK
SCALE. 20 FT — 1 INCH

Now if the spaces between AB, and BC, be filled with any good filtering materials, as fine-washed sand or the *bujree* used by masons, the water which enters through A (being the surface water which is always the clearest)† will filter through it downwards beneath B and upwards to C. If these spaces be ten feet deep only, this gives twenty feet of filtering distance, in every inch of which the water will leave some of its impurities. A small wall and sluice outside of A would cut off the communication and enable us to clear out our filtering apparatus and re-fill it with fresh materials. It is probable that no water would require more filtering than this to come perfectly limpid into the reservoir, but if any did so, another pair of walls might be added. They may be tolerable close; say just far enough apart to allow a man to work in clearing out the material when it requires changing, for it is to be noted that the efficiency of this filter depends upon its *depth*, and not on its breadth at all.

It is evident that walls may be built to any extent required, either merely to inclose a ghat, or a corner of a tank, or across a whole side of it; and that arrangements may easily be made for preventing the fouling of the limpid water, when filtered, by those who take it for use.

† Some of the hole at A, &c., are always supposed to be below the level of the tank, when at its lowest level in the dry season.

soldiers we have here nothing to do, but the equally important question of providing regular occupation and amusement for their leisure hours, has its Engineering as well as its social aspect. All the new barracks have a workshop and reading room provided in each, besides which a five's court and skittle alley are provided for each regiment. Regimental workshops have also been initiated, in which lathes, forges, and such like heavy fixtures should remain as parts of the building, and be made over by one regiment to another on its relief. In these workshops, carpenter's, blacksmith's, and other work has been executed and sold at a remunerative price, and a late Government order promises to take all necessary barrack furniture and fittings from such shops; but although the experiment has in isolated cases been successful, it is obvious that much must depend on the constitution of each individual regiment, and that it will always be difficult for European labor to vie in economy with that of skilled natives. Still the European in this case has not to live by his labor, and can therefore sell it at a price which under other circumstances would not be remunerative.

It is understood that the attention of Government is also directed to a point very much affecting the soldier's comfort, viz., the proper lighting of barracks at night. In the barracks at Fort William, gas has been laid on for this desirable purpose, and proposals invited from the Oriental Gas Company to light other stations where Coal gas is available. How far Oil gas* can be utilized where the former is not obtainable, is a point still to be ascertained. The proximity of most cantonments to large native cities ought to make it worth while to erect expensive works to supply both at each place, provided only the raw material can be obtained.

Enough has been said to show that the attention of Government is and has been for some time past earnestly directed to obviate or lessen the evils complained of, and it will also be seen that on many points difficulties have to be overcome which demand serious consideration.

---

* Major Robertson, Superintending Engineer, Indus Tunnel works, states the yield of gas from mustard oil at 70 cubic feet per gallon. At the average price of this oil this would amount to 10 Rs. per 1,000 cubic feet. The fuel would cost eight annas, and the establishment and apparatus probably 1 R. 8 As. making the total cost of 1,000 cubic feet of gas, 12 Rs. This is about double the average cost of coal gas in the South of England, but would probably be found not dearer than the present cost to Government of the present wretched oil-lights.

J. G. M.

No. IX.

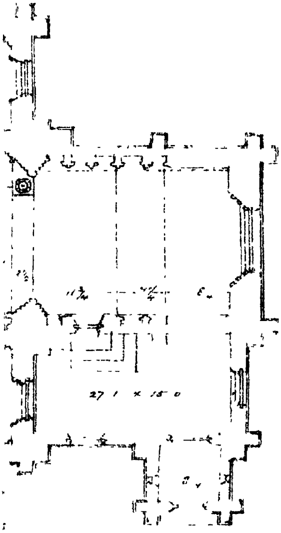
TRINITY CHURCH, SEALKOTE.

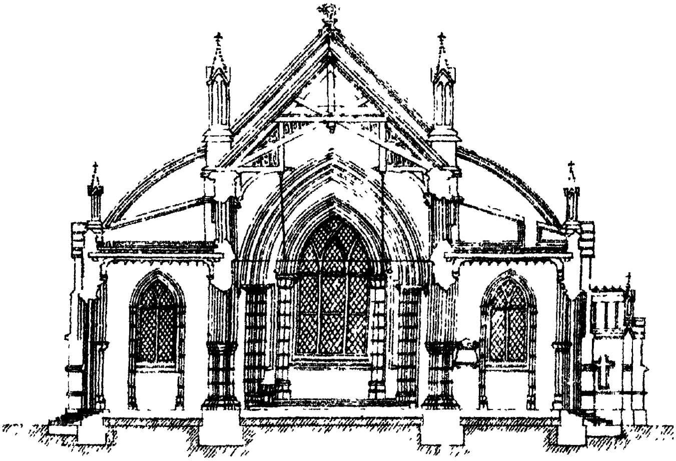
Designed and built by LIEUT.-COLONEL J. H. MAXWELL, *Royal Engineers.*

THE Church and Tower were completed in 1853, at a cost to Government of Rs. 41,000; the additional expenditure, the amount of which has not been ascertained, having been met from private subscriptions. In this Church, zinc sheeting was adopted with success in the covering of the roof.

The Spire was built in 1861, on Colonel Maxwells' original design, at a further cost of Rs. 3,869.

The photograph is by Mr. J. Freeman, of the Thomason College.




Section.

No. X.

NAVIGABLE RIVERS AND CANALS IN THE NORTH WESTERN PROVINCES.

[In 1861, the Government of India (Home Department) having called for a Report on the number and nature of the Navigable Streams in the N. W. Provinces, the Commissioners of Divisions were asked for information on the subject, and the following Abstract was drawn up from their reports, by the Secretary to Government, N. W. Provinces, P. W. Department.]

GENERAL ABSTRACT OF REPORTS BY COMMISSIONERS OF DIVISIONS ON NAVIGABLE RIVERS, IN THE NORTH WESTERN PROVINCES.

RIVER GANGES.

MEERUT DIVISION. RIGHT BANK, 171 MILES.

District.	*Right Bank.*	*Left Bank.*
Saharunpore,	30	,,
Moozuffurnugger,	50	,,
Meerut,	53	,,
Boolundshuhur,	43	,,
Allygurh,	5	,,

ROHILCUND DIVISION. LEFT BANK, 233 MILES.

Bijnour,	,,	88
Moradabad,	,,	40
Budaon,	,,	95
Shajehanpore,	,,	15

AGRA DIVISION. RIGHT BANK, 60 MILES.

Furruckabad,	60	,,

ALLAHABAD DIVISION. RIGHT BANK 220 MILES.

District.	*Right Bank.*	*Left Bank.*
Cawnpore, - - - - - - - -	70	(Oudh)
Futtehpore, - - - - - - - -	65	do.
Allahabad, - - - - - - - -	85	do.
BENARES DIVISION. RIGHT BANK, 235 MILES.		
Mirzapore, - - - - - - - -	70	,,
Benares, - - - - - - - - -	35	,,
Ghazeepore, - - - - - - - -	130	,,
Total,	686	233

The whole course of the Ganges in the North Western Provinces, is about 686 miles in length. It is navigable throughout the year. From the Moradabad district upwards, there is no dry weather trade. In the Budaon and Shajehanpore districts, boats of 500 maunds pass up and down, both in the rainy and dry seasons. From the Furruckabad district downwards, boats of from 700 to 1,000 maunds can always go up and down freely; as a general rule, however, boats proceeding down stream with the current in their favor carry heavier cargoes than those which are being tracked up against the stream.

In the year 1835-36 a steamer from Allahabad passed up and arrived at Gurhmookhtesur in the district of Meerut, but the experiment was not considered sufficiently successful to encourage further trial.

The Commissioner of Agra considers that steam-boats drawing like those on the Rhine or Elbe, from two and a half to three feet of water would find no difficulty on this river, if the rocks and shoals were properly ascertained and the channels marked off. The river is, however, extremely winding in its course, and its shoals and sands shift with each recurring rainy season.

Since the opening of the Ganges Canal the capabilities of this river for navigation have been greatly diminished.

RIVER JUMNA.

MEERUT DIVISION. LEFT BANK, 213 MILES.

District.	*Right Bank.*	*Left Bank.*
Saharunpore, - - - - - - - -	,,	65
Mozuffurnugger, - - - - - - -	,,	40
Meerut, - - - - - - - - -	,,	53
Boolundshuhur, - - - - - - -	,,	42
Allygurh, - - - - - - - -	,,	13

AGRA DIVISION. LEFT BANK, 292 MILES.

District.	*Right Bank.*	*Left Bank.*
Muttra.	„	77
Agra,	„	105
Mynpoory,	„	25
Etawah,	„	85

ALLAHABAD DIVISION. RIGHT BANK 105 MILES. LEFT BANK, 243 MILES.

Cawnpore,	„	73
Futtehpore,	„	105
Banda,	105	„
Allahabad,	„	65

JHANSI DIVISION. RIGHT BANK 130 MILES.

Humeerpore,	35	„
Jaloun,	95	„
Total,	235	748

The Jumna in its course through the North Western Provinces, is about 748 miles in length. It is navigable throughout the year for boats averaging from 500 to 1000 maunds. The river in the upper portion of its course has a bed of boulders broken at intervals by strong rapids. Below Delhi the bed is generally sandy, presenting no obstacles to navigation beyond a shifting channel and occasional bars and shoals common to beds of such nature. Along this latter portion of its course the main channel, although variable in position, is very uniform in width and depth. The river is at its lowest from December to March, presenting in years of average rain-fall, a tolerably uniform depth of one and a half to two feet along its course in the Meerut division. If the cold weather rains be plentiful, the depth increases to three or three and a half feet, and the melting of the snows at its source raises it to four feet from the beginning of April to the end of May. In the rains the depth is from six to twelve feet.

In 1855, the Commissioner of Delhi, with a view of ascertaining the practicability of running an Iron Steam Boat between Delhi and Muttra, despatched an English built boat drawing from three to four feet of water in the middle of June before the commencement of the rainy season, which reached her destination in perfect safety, demonstrating thereby the perfect practicability of a regular daily water communication by vessels not much exceeding that draught of water.

The course of the river in the Muttra district is much obstructed by rocks, but which the Commissioner thinks, could easily be removed by a few blasting operations. The depth here is from three to four feet in the dry months. After leaving Muttra, the river in the Agra district is considerably more tortuous in its character, the depth in the dry months not more than one and a half feet, and in the rains from twelve to fourteen feet. The Magistrate of Agra, proposes to straighten and reduce the river by cuttings wherever it is most tortuous, for instance in the Bah and Futteabad pergunnahs. The bed of the river here is, however, very deep and its banks rocky, and it is apprehended that the work would be costly beyond the value of any object to be gained.

For some years a Company of Sappers and Miners was employed in the Etawah district, in clearing away the rocks and obstacles that imprison the Jumna a few miles below Sheregurh near Bhuduk, but much yet remains to be done to make the river safely navigable for a steamer; with this exception the Jumna in its entire course through the Etawah district would be navigable by any steamer not above ninety or hundred feet long and not having a draught, when laden, of more than four feet, inclusive of keel.

The navigation of the Jumna in the Allahabad division is more difficult than that of the Ganges; the bed of the river in several places is crossed by ledges of rock and beds of kunkur and clay, by which the the depth of water is reduced and the navigation rendered dangerous. Boats of 500 maunds can navigate the river in the Allahabad district and steamers up to Allahabad.

In the Humeerpore and Jaloun districts the river is sufficiently deep to allow steamers of the same draught as now ply between Calcutta and Allahabad, being used. The quick sands are not so common about here and the river is free from stumps of trees, which are so injurious to river navigation. With a small outlay the Deputy Commissioner of Jaloun thinks, that the river could be cleared for the navigation of flat bottomed steamers, such as are used on the Indus.

The Commissioner of Agra is of opinion that both the Ganges and the Jumna may be made infinitely more useful for the purpose of navigation, then they have hitherto been. He believes that the class of steam boats best adapted for dealing with the sand, shoals, and shallows of these streams has never yet been introduced into India. Vessels drawing from one foot to eighteen inches of water, exceedingly strong and yet carrying a large bulk of cargo, are in daily and nightly use in Europe, and on the rivers of North America, and with a proper establishment of river pilots and some application of Engineering skill, the Commissioner sees no reasons why both these rivers may not be traversed by steamers with safety, both by day and night.

RIVER SOTE, OR YAR WUFFADAR.

ROHILCUND DIVISION.

District.	*No. of miles.*
Moradabad,	45
Budaon,	65
Shajehanpore,	15
	125

The total length of this stream is 130 miles. It takes its rise at Amroha, in zillah Moradabad, and flows into the Ganges in the district of Shajehanpore. At present it is used for crafts of 100 maunds tonnage in the rains, and 50 in the early part of the dry weather. The Commissioner thinks that it would be worth while having professional opinion as to its capabilities of navigation for about forty miles of its course, as far as Budaon.

RIVER RAMGUNGA.

ROHILCUND DIVISION.

District.	*No. of miles.*
Bijnour,	35
Moradabad,	55
Rampore,	20
Bareilly,	60
Budaon,	15
Shajehanpore,	25
	210
AGRA DIVISION.	
Furruckabad,	20
	230

This river in the earlier part of its course from the foot of the hills, for about 200 miles, is not used even in the rains for navigation. Lower down from Bareilly for eighty miles, it is much used during the rains by boats of 1,000 maunds, and at a drier period, for boats of 500 maunds. But from October to July navigation ceases. It is a shifting and unmanageable stream, and would not admit of a remunerative outlay to improve its channel.

RIVER DEOHA, OR GURRA.

ROHILCUND DIVISION.

District.	*No. of miles.*
Pilleebheet,	40
Bareilly,	30
Shajehanpore,	50
	120

This river rises in the Kumaon hills and enters the Ramgunga in Oudh, just before that river falls into the Ganges. During the rains, boats of 250 to 300 maunds navigate from Pilleebheet, and of 500 maunds from Shajehanpore. It is not navigable during the dry weather.

RIVER CHUMBUL.

AGRA DIVISION.

District.	*No. of miles.*
Agra,	45
Etawah,	43
	88

This river takes its rise near Munder in Malwa within fifteen miles of the Nerbudda, and falls into the Jumna below Etawah. It is reported to be used *infrequently* by small boats, but can hardly be called navigable. In the rains it is a furious torrent, and in the dry months so obstructed by rocks as to be only deep enough in its channel for small boats. Engineering skill might make its lower course navigable in the cold months.

RIVER TONSE.

ALLAHABAD DIVISION.

District.	*No. of miles.*
Allahabad,	40
	40

The Tonse is navigable for about twenty miles from its mouth, but there is a bar at the junction with the Ganges, which forms a serious obstacle to the entrance and exit of boats. For the short distance in which, under the most favorable circumstances, this river could be employed for the transport of goods, any outlay in its improvement would be unproductive.

RIVER NERBUDDA.

SAUGOR DIVISION.

District.	*No. of miles.*
Mundla,	45
Jubbulpore.	78
Nersingpore,	83
Hoshungabad,	120
	326

This river is only navigable in short patches in the rains, owing to the fall of the river being in steps. It rises at Umerkuntuk, 3,300 feet above the sea, in the Sobagpore pergunnah, in the Rewah territories, and falls into the sea at Baroche, in the Bombay presidency. One of the selections from the Bombay Government Records describes the physical character of the river.

RIVER GOGRA.

GORUCKPORE DIVISION.

District.	*No. of miles.*
Goruckpore,	150
	150

Steamers can ply only in the rainy season without fear of being grounded. Large native boats of 1,000 or 1,500 maunds can go up and down the river in the hot season.

RIVER KOANA.

GORUCKPORE DIVISION.

District.	*No. of miles.*
Goruckpore, - - - - - - - -	70
	70

In the rainy season large native boats of more than 2,000 maunds can go up and down the river, but in the hot weather boats of about 500 maunds only can pass in it. The river flows through the most populous and productive part of the district.

RIVER RAPTEE.

GORUCKPORE DIVISION.

District.	*No. of miles.*
Goruckpore, - - - - - - - -	130
	130

In the rainy season large native boats of more than 2,000 maunds can go up and down the river, but in the hot weather boats of about 500 maunds only can navigate it.

RIVER CHOTEE GUNDUK.

GORUCKPORE DIVISION.

District.	*No. of miles.*
Goruckpore, - - - - - - - -	110
	110

Navigable by boats for eight months. It almost dries up during the hot season in some places. Many large bazars are on this river, and the neighbouring country productive. When the season affords a sufficient depth of water there is very considerable traffic down this stream.

RIVER BURREE GUNDUK.

GORUCKPORE DIVISION.

District.	*No. of miles.*
Goruckpore,	75
	75

In the rainy season large native boats of 400 or 500 maunds can go up and down this river. Steamers can also navigate in the rainy season.

RIVER DHAMALA.

GORUCKPORE DIVISION.

District.	*No. of miles.*
Goruckpore,	15
	15

Boats of 500 maunds navigate this river in the rainy season. In the hot months it is very shallow.

RIVERS BOORHEE RAPTEE, AND BANGUNGA.

GORUCKPORE DIVISION.

District.	*No. of miles.*
Goruckpore,	45
Goruckpore,	25
	70

Both these streams are natural canals in which water remains all the year round, even during the dry season. There is always a moderate current in them.

RIVER ROHIN.

GORUCKPORE DIVISION.

District.	*No. of miles.*
Goruckpore,	55
	55

Wood rafts come down this stream from the jungles; also grain canoes. The river throughout its entire course flows past forests and wastes, and having no bazar near its banks, it is not navigated by boats.

RIVER SURGOOR, OR TOUNSE.

BENARES DIVISION.

District.	*No. of miles.*
Azimgurh,	70
Ghazeepore,	33
	103

Can be navigated in the rainy season by boats of 500 maunds all through the Azimgurh district. Boats of 1,000 maunds can likewise ascend in the rainy season to a distance of thirty miles from its mouth.

RIVER GOOMTEE.

BENARES DIVISION.

District.	*No. of miles.*
Jounpore,	55
Ghazeepore,	10
	65

Can be navigated in the rainy season by boats of 1,000 maunds to beyond Jounpore, and by boats of 200 maunds all through the division at all seasons of the year.

RIVER SAEE.

BENARES DIVISION.

District,	*No. of miles.*
Jounpore,	45
	45

Can be navigated only in the rains by boats of 100 maunds.

RIVER BURNA.

BENARES DIVISION.

District.	*No. of miles.*
Benares,	28
	28

Can be navigated in the rainy season to a distance of thirteen miles from its mouth, near Benares, by boats of 200 maunds.

GANGES CANAL.

MEERUT DIVISION. 217 MILES.

District.	*No. of miles.*
Saharunpore,	33
Mozuffurnugger,	35
Meerut,	50
Boolundshuhur,	35
Allygurh,	64

AGRA DIVISION. 102 MILES.

Mynpoory,	62
Furruckabad,	40

ALLAHABAD DIVISION. 42 MILES.

Cawnpore,	42

GANGES CANAL. FUTTEHGURH BRANCH.

MEERUT DIVISION. 216 MILES.

District.	*No. of miles.*
Mozuffurnugger,	16
Meerut,	35
Boolundshuhur,	55
Allygurh,	20

ROHILCUND DIVISION. 7 MILES.

District.	*No. of miles.*
Budaon,	7

AGRA DIVISION. 30 MILES.

Mynpoory,	15
Furruckabad,	15
	163

GANGES CANAL. ETAWAH BRANCH.

MEERUT DIVISION. 25 MILES.

District.	*No. of miles.*
Allygurh,	25

AGRA DIVISION. 10 MILES.

Muttra,	5
Mynpoory,	49
Etawah,	48

ALLAHABAD DIVISION. 50 MILES.

Cawnpore,	50
	177

EASTERN JUMNA CANAL.

MEERUT DIVISION.

District.	*No. of miles.*
Saharunpore,	54
Mozuffurnugger,	30
Meerut,	47
	131

No. XI.

ARCHING OF THE MORHUR BRIDGE, BENGAL.

From Captain C. J. Mead, *Executive Engineer, 2nd Division, Grand Trunk Road, to the Superintending Engineer, Behar Circle.*

17th July, 1863.

Sir.—I have the honor to report for record in your Office, and, should you think fit, the information of the Chief Engineer and Government, (your presence on the spot, and my having continually had the advantage of your personal advice and instructions, renders it unnecessary I should do so for your information), that we have completed the arching of the centre section of six arches (74 feet span) of the Morhur Bridge, and struck the last centre on the 10th instant. I annex in a Tabular Form a Memorandum, shewing the dates on which we commenced, completed, and struck each arch, and the amount of sinking at the crown, on removing centres.

I annex a drawing of the centres we used, which proved perfectly efficient, and a small sketch shewing the somewhat unusual method adopted to strike the centres, which answered so well, and is, I have reason to think, so superior to the usual method of wedges, that I venture to add a brief memorandum describing it in detail.

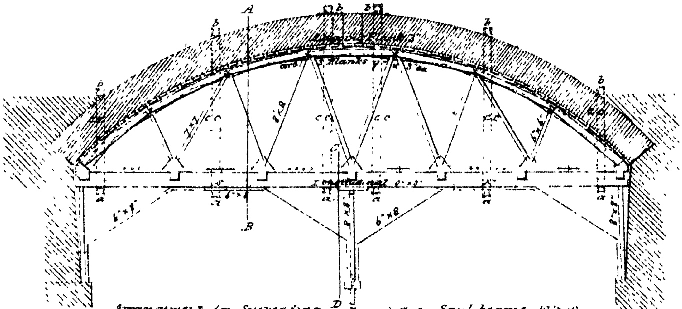
The arches have been turned in five concentric rings, each one brick or nine and a half inches thick, laid alternately header and stretcher; great care being taken to set them with as fine joints as possible, and a perfect bond in each ring being obtained by the use of two and a half bricks moulded for the purpose in each alternate course. The bricks were set in excellent kunkur lime mortar, ground under stone rollers on the bank of the river, and conveyed mixed in small tip trucks made for the purpose along our tramway to small tanks opposite to each pier, from whence it was hoisted in boxes over wooden pulleys to the tops of the piers, as required, by the women in attendance on the masons. The bricks were similarly brought from the brick field, a distance of about half a mile in trucks, from which they were stacked in tanks full of water until wanted, and thence passed from hand to hand by a line of women seated on ladders placed against the cutwaters of the piers.

As will be noticed from the Tabular Statement annexed, the amount of sinking at the crown, on removal of centres, has been, I think, exceptionally small in arches, Nos. 5, 6, 7, 8, and 9. I attribute this to the excellent material used, and particularly to the very perfect form of our bricks which, (moulded on tables on the English stock moulding system, as introduced by Mr. Power, of the East Indian Railway, at the Soane Bridge works, and which I succeeded in introducing here by the assistance of a trained moulder whom his successor kindly obtained for me,) are, I think I may say, equal, if not superior, both in strength and shape to any ever made in Bengal. No. 10 arch sunk much more; indeed so much more than had been anticipated from our experience of those struck previously, that, not having allowed sufficient space above the blocks on which the centre was to rest after striking, it was necessary to lower the centre a second time, and, as might have been expected under the additional motion, slight cracks shewed themselves for a few feet on each side of the crown between the first and second, and second and third rings, of which the arch is composed. These, however, are so trifling that they are imperceptible after pointing and I believe, quite immaterial with reference to the strength and stability of the arch, and are the only cracks or flaw of any kind which exist in our work, consisting of 58,000 cubic feet of brick masonry, all executed between the 15th April and the 22nd June.

There being some fear that, if we attempted to remove all the centres, the setting in of the rains, producing the usual heavy floods in the river, might cause damage, and perhaps loss of some portion of these valuable framings, which took a long time and much labor to construct, I gladly adopted and carried out a suggestion of yours, and have suspended the whole of the upper portion of the centres to the

MORHUR BRIDGE CENTRE.

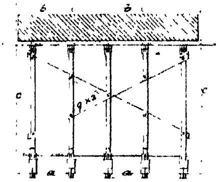
Elevation



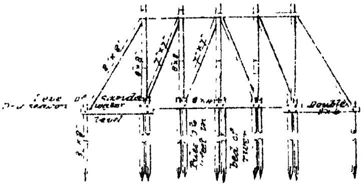
Arrangement for Suspending Centre after removal of lower Supports, dotted

a a a Saul beams 10"×10"
b b b Auson do 8"×8"
c c c ¾ Iron bolt suspension rods

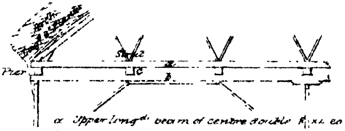
Transverse Section on the line A B



Transverse Section on the line C D

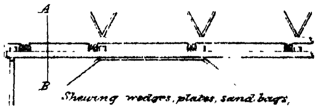


Side Elevation of part of Centre during construction of arch



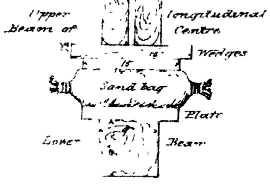
a Upper long^l beam of centre double 8 x 12 ea
b Lower do do do do 9 x 9
c Block 12"×8×8

Side Elevation of part of centre just before striking

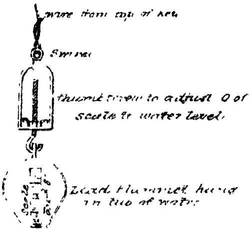


Shewing wedges, plates, sand bags, and blocks laid on their sides

Transverse Section on line A B (enlarged)



Thumb Bob


wire from top of key
Swivel
thumb screw to adjust 0 of scale to water level.
Lead Plummet hung in tub of water
Scale

arches by means of temporary cross beams above the arches and below the horizontal beams of the centres, connected with vertical bolts of ¾ inch rod iron, and have only removed the vertical standards and struts which would have been in the waterway. Each complete centre, consisting of five trusses, with the lagging and its coat of plaster, weighs about 43 tons, and is supported by twenty-four drop bars of ¾ inch bolt iron, (to avoid any risk from faulty welds, every drop bar has been tested with a strain of 2½ tons, it has only 1·8 tons to carry, while its calculated breaking load would be ·44 × 20 tons = 8·8 tons) and by this most convenient arrangement the whole of our centres remain in place for the rains under the arches which have been turned on them, (which form a first-rate roof for their protection from the weather,) and are most conveniently placed for removal and re-erection when we commence work in November.

This work has been a most anxious one, being a larger job than I or any member of my establishment had ever seen executed before in India, (I believe they are the largest arches that have been completed in Bengal up to date) and one which it was necessary to complete in a given and short time. I have great pleasure in bringing to your notice, and shall be obliged by your reporting to the Chief Engineer, the conduct and exertions of the Establishment employed—Assistant Engineers Mr. J. Luff and Mr. Mansfield; Assistant Overseer Abbott; and Sub-Overseers Hutton, Thompson, and Burney; while I would especially record my sense of the services of Assistant Engineer Mr. Luff, who has been in immediate charge of this work, and to whose professional knowledge, constant attention to details, and real devotion to his duty, I consider the chief portion of our success due.

MEMORANDUM ON THE METHOD ADOPTED IN STRIKING THE CENTRES OF THE MORHUR BRIDGE, AT SHERGHOTTY, IN 1863.

In arranging the details of the centres for the arches of the Morhur and Boorya Bridges at Sherghotty, after designing the main details of the trusses to carry the weight of the arches, the arrangements for striking them, after the arches were keyed, appeared important. While, considering the arrangements to be made, Captain Mead came across an interesting account (in the Supplementary Volume of Weale's Bridges, an extract of which is annexed for reference,) of a method which had been adopted in striking the centres of a Bridge over the Creuse, at Port-de-Pile, on the Orleans and Bordeaux Railway, where the weight of the centres, and of that portion of the arch resting on them, was transferred after keying, from blocks to sacks filled with sand, the mouths of which being opened simultaneously, the sand running out lowered the centres gradually and uniformly without effort, thus avoiding the difficulty of lowering uniformly by striking back a number of wedges simultaneously, where it frequently occurs that some wedges suddenly slip and fly back at once, while others are jammed hard and require much trouble and heavy blows to start them.

These difficulties appeared to be more likely to occur in striking a large centre in India than in Europe, where some little reliance may be placed in the exercise of a little intellect by every workman, while at Sherghotty we could not expect the exercise of any by those employed, with exception of the three or four Europeans who could be collected to superintend.

A trial having been satisfactorily made by wedging up and lowering a platform of timbers loaded with a mass of stone, it was decided to adopt a modification of the plan described, and our arrangements were consequently made as follows:—

The centres were designed with double longitudinal beams, the lower one carried on the posts and struts forming the supports of the centre, and the upper one forming the tie to the series of triangles forming the upper portion of the centres (*vide* drawing). This upper beam rested on the lower at a distance of 12 feet through blocks 8″ × 8″ × 12″ of soft easily splitting wood, *(dhow)*. When the arch had been keyed, a strong sack made of double coarse country canvas *(tat)* made as a tube, filled with dry sand and tied with string at both ends, was introduced between these two beams close to each block, a plate of stout plank (12″ × 15″ × 2″) being placed above and below to distribute the pressure fairly over the bag; and finely tapered wedges in pairs were driven between the upper plate and the upper longitudinal beams with heavy mallets, until the weight of the centres in lieu of resting on the blocks, was borne by the sand bags, and the blocks were so far loosened that they could be easily driven out of their places with a few blows of the mallets. Any individual blocks which could not be thus relieved, or were jammed, were split out by carpenters, but this was not found necessary in more than two or three cases. The blocks were then re-introduced into their places, but laid on their sides instead of on end, thus leaving a space of four inches between their upper surfaces and the lower side of the upper longitudinal. The whole centres now rested on the bags, of which eight supported each truss, or forty the complete centre. Eighty ordinary coolies were now brought up, two to each bag, (one taking charge of each mouth) and two or three Europeans posted among them to see, and report, each order obeyed. The word was then successively given, *first*, to untie the up-stream mouths of each bag but not to allow any sand to escape; *second*, to untie the down-stream mouths; *third*, to allow the sand to run out of the bags, when the whole of the centre sank gradually and steadily until it again rested on the blocks placed to receive it, leaving the arch unsupported.

It was really a very pretty sight to see the large mass of complicated timber framing 74′ × 24′ × 16′, and weighing nearly 50 tons, besides the portion of the weight of the arch of masonry resting on it, gradually subside, with a motion so slow and smooth that it was perfectly unnoticeable even while standing on it, except by the separation between the lagging and the arch, and the approximation between the longitudinal beams; so uniform was the motion, that not even a creak was heard from any joint of the frame, and the time occupied by the movement did not exceed one minute. The amount of sinkage at the crown of the arch was accurately noted by means of two heavy leaden plummets weighing 8 to 10lbs. each, and having a small brass scale attached, one of which was hung from either side of the crown by an iron wire, and rested in a tub of water below to check any oscillation of the plumb bob; consequently the depth to which the scale was immersed before and after striking, being carefully noted, the difference shewed the exact amount the crown of the arch had sunk; this measurement was further checked in some arches, by observing a point on the key of the arch from a distance, through the telescope of a theodolite.

C. J. Mead.

EXTRACT FROM AN ACCOUNT OF THE BRIDGE AT PORT-DE-PILE OVER THE ORLEANS AND BORDEAUX RAILWAY.

(Weale's Bridges, Supplementary volume, page 109.*)*

" A very ingenious mode of striking the centres was introduced in the bridge of the Port-de-Pile for the purpose of easing them gradually and without shocks, from which cause such serious inconveniences arise in the generality of cases. In many bridges it has been found impossible to drive back the wedges towards the middle of the span, even when a sheet of metal has been interposed, owing to the enormous insistent pressure. It becomes often necessary in such cases to place narrower wedges by the side of the original ones, and to cut away the latter. The centre then drops suddenly, perhaps, communicating its motion to the masonry; and, moreover, as it is impossible to cut away the wedges with perfect regularity, the centre becomes deformed in its descent, or one rib of a centre may be loosened before the rest, either causing distortions of the masonry, or rendering it necessary to restore that rib to its place by screw jacks to relieve the others still in their original positions.

" As M. Boudemoulin observed, the difficulty of producing movement in the wedges arises from the fact that the fibres of the wood in the inclined faces penetrate into one another from the effect of their load, and the alternations of dryness and moisture they are exposed to. The force which can be exerted upon them at the moment of striking the centres is never sufficient to overcome the friction arising from these causes.

" Experiments were tried to ascertain whether the difficulties attached to striking the centres might be obviated by placing the ribs upon fir sills during the execution of the work; the intention being to place wedges by their side at the moment of easing the centres, and cut away the sills, so as to leave the ribs upon the wedges, which were then to have been lowered. The maximum weight able to be brought upon one pair of wedges was 45 tons in the bridge of the Port-de-Pile.

" Wedges of oak, whose sides were inclined in the proportion of 1 in 3½, the faces being well greased being intercalated, were placed under an hydraulic press, and exposed to an action equivalent to a weight of 50 tons, yet they did not slide upon one another even when struck with a large hammer. Other wedges of a compound nature, in three pieces, the top and bottom ones having one face horizontal, and the middle piece two inclined faces of 1 in 4, were tried without producing a more favorable result. The inclination of the middle piece was carried as far as 1 in 3 on each side, but still there was no spontaneous movement.

" Sacks filled with sand were then placed under the press, the cloth of which they were made being very strong, and in the experiments the sand was dried. The flow of the sand through the necks took place with the regularity of a clepsydra, and it was at any moment stopped by merely tightening the string. The weight was increased to 60 tons, but was as perfectly under control as before; even with an opening in the sack of 1 foot 4 inches long, the flow was, regular, and no sudden fall occurred.

" In consequence of the success of the experiments upon the sand in the sacks, the system used in this bridge was decided upon. It consisted in placing immediately over each point of support of the centres, block of fir on end, about 1 foot 4 inches square, the total number being 36 per arch. When it was desired to lower the centres, sacks (of common strong cloth made open at both ends, and merely closed by a strong cord) filled with sand, were placed close against these blocks. The sacks to be placed at the points where the weight was greatest were double, and in all cases they were bound round the middle by a cloth to increase the resistance in that portion. A small tube of cloth filled also with sand was introduced in the centre, to form, as it were, a nucleus. The sacks when completed were thus cylinders of about 1 foot 2 inches in diameter, by about 1 foot 4 inches long. They were placed upon a thin plank, and wedged up to the under sides of the sill by fir wedges.

" The upright blocks were then cut away gradually, and the weight was brought upon the sand bags. The first movement was produced by the compression of the sand, which was observed to be about 1 inch. The mouths left at the ends were then opened, and care was taken to regulate the flow of the sand, so as to obtain a regularity of descent by means of a small wood frame at the mouth. As soon as the centre became detached from the arch, the ends of the sack were opened to their full extent, and the flow of the sand expedited, so as to lower the whole centre about 1 foot, at which height it might either be left, or a series of wedges of the remaining distance between the sill and the supports might be introduced, to enable the sacks to be withdrawn and the descent continued.

" It was found that dried sand pressed very closely upon the sacks occasionally destroys them; with sand in its ordinary state, they were found to resist better, but the escape was also less easy, for the pressure tended to make the sand aggregate. As an additional precaution, small blocks, varying in height as the centres were lowered, were introduced to receive them in case of any sudden depression of the sacks; but in no case were they ever brought into action, so perfectly did the system answer. Indeed, during the whole time the operation of easing the centres was going on, no noise or creaking of the wood was heard, and it was only by measuring the distance between the sill and the top rail of the framework upon which the centres rested, that the lowering of the former could be perceived; nor could the separation of the centre from the arch be distinguished without observing the latter very closely. It was thus evident that the system of easing the centres followed in this instance allows them to subside gradually, so that the voussoirs cannot assume abruptly any movement; and, inasmuch as all the bearing points sink gradually, the pressure are uniformly distributed. The system was applied for the three arches of thes bridge of the Port-de-Pile, and also for four arches of a bridge over the Vienne, cn the same railway, with perfect success; so that a sufficient number of practical experiments confirm its merits. The expense is also very insignificant, for the sacks, when single, only cost 3*s.* 4*d.*, and when double, 6*s.* 3*d.*; with some slight repairs the same sacks served for the seven arches."

STATEMENT SHEWING THE DATES OF COMMENCEMENT OF MASONRY, KEYING OF ARCH, AND THE STRIKING OF CENTRES, WITH THE AMOUNT OF SETTLEMENT OF EACH OF THE SIX ARCHES COMPLETED OF THE MORHUR BRIDGE IN 1863-64.

(Span 74 feet, versed Sine 15 feet.)

Number of Arch.	Date of commencement of Masonry.	Date of keying the last ring.	Date of striking centres.	Amount of Settlement of Arches.		
				At once.	During next 24 hours.	Total.
5	April 20th	June 9th	June 9th	$\frac{5}{8}''$	$\frac{1}{16}''$	$\frac{11}{16}''$
6	„ 15th	„ 3rd	„ 5th	$\frac{3}{8}''$	$\frac{1}{8}''$	$\frac{1}{2}''$
7	„ 16th	„ 7th	„ 7th	$\frac{5}{8}''$ bare	...	$\frac{5}{8}''$
8	„ 18th	„ 9th	„ 10th	$\frac{7}{8}''$	...	$\frac{7}{8}''$
9	„ 27th	„ 22nd	July 10th	$\frac{1}{2}''$	$\frac{1}{16}''$	$\frac{9}{16}''$
10	„ 24th	„ 20th	June 20th	$2\frac{3}{4}''$	$\frac{1}{8}''$	$2\frac{7}{8}''$

C. J. MEAD.

MEMORANDUM BY THE SUPERINTENDING ENGINEER.

FORWARDED to the Chief Engineer with two drawings and three copies of photograph. The undersigned has nothing to add to the Executive Engineer's Report, he has been present throughout, and has witnessed the exertions of all hands in executing this work.

The bricks used throughout were excellent, the mortar very good indeed. The way the arches have been turned in 9½ inch* concentric rings was ordered by Superintending Engineer, and the result is perfectly satisfactory; there is no brick-work in all India superior to that in these six arches, as is proved by the very trifling subsidence on lowering the centres; the one arch that sunk $2\frac{7}{8}$ inches was struck too soon after completion; for owing to a failure in the supply of bricks, Nos. 9 and 10 had to be stopped for half of May, and they were only proceeded with vigorously in June; but what is a sinkage of $2\frac{7}{8}$ inches in an arch of 74 feet span, the rise being 15 feet ?

---

* One brick on end, and two on edge, alternately.

The mode adopted of supporting the centres on the arches has proved very satisfactory; and a vast amount of time and labor has been thus saved. Everything has been done by Captian Mead systematically and with care, and complete success has attended all his arrangements. The services of this officer and of Mr. Assistant Engineer Luff are very strongly recommended to the notice of the Chief-Engineer; few can understand, but those on the spot, the amount of exposure and anxiety they have both undergone during an unusually hot season.

Mr. Probationary Assistant Engineer Mansfield has been present throughout the arching, and had his share of exposure and hard work, and has proved himself an admirable assistant; the Overseers named have worked cheerfully and well; and Superintending Engineer hopes the result now reported will be considered altogether satisfactory and creditable to the Public Works Department.

W. Maxwell.

20th July, 1863.

No. XII.

EUROPEAN INFANTRY BARRACKS, NOWSHERA, PUNJAB.

Erected in 1855, *by Lieut. (now Captain) F. S. Taylor,*

[These Barracks are modifications of those originally designed for the Punjab cantonments; each building containing a half, instead of a whole, company, and the wards being separated from each other by doors instead of archways, so as to form complete rooms for 12 men each. The frame work of the roof is of iron; the floors are of slate, procured from the neighbouring Khuttuk hills. It is believed that no Barracks, as yet constructed in India, are better built or surpass these in comfort and healthiness.—Ed.]

SPECIFICATION.

Each Barrack to accommodate one company, consists of two wings connected by a passage 30 feet long.

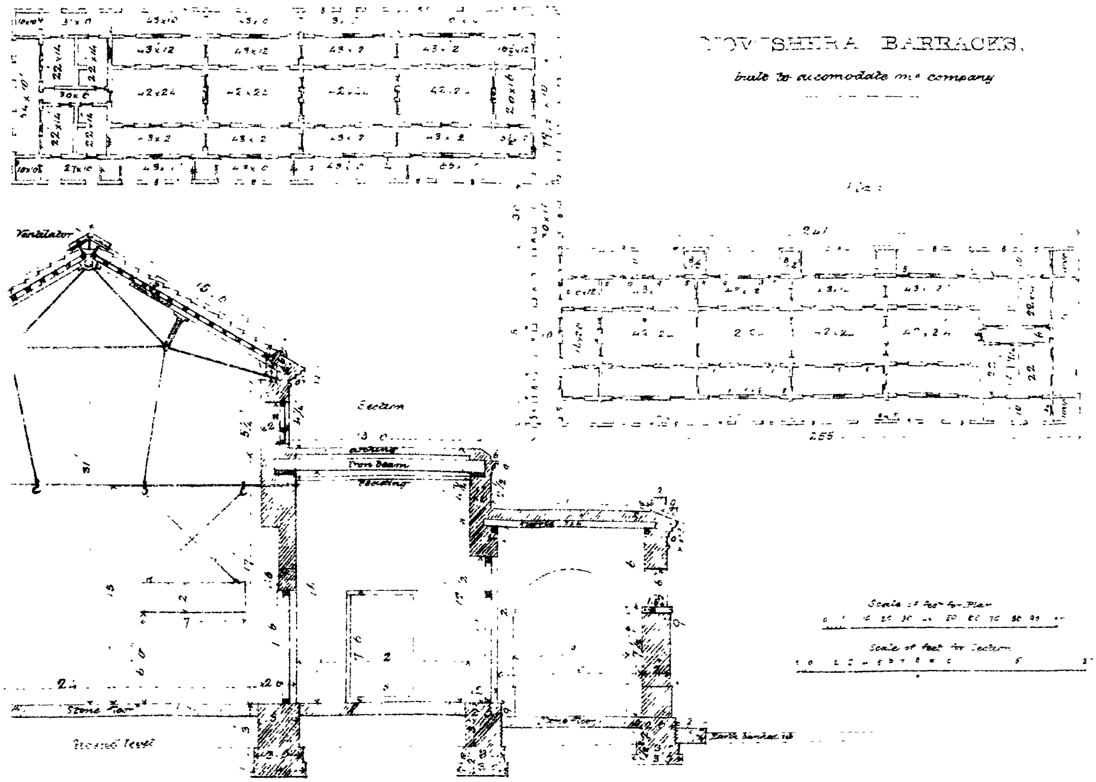
In each wing there are four main rooms, 42 × 24 feet, with a reading room or workshop, 26 × 16 feet, at one end; and four rooms 22 × 14 feet, for the accommodation of the Sergeants at the other end. The inner enclosed veranda is twelve feet wide with double doors. The outer veranda is open, ten feet wide, the archways being eight feet span.

The main walls are twenty-two feet in height from the level of the floor to the top of the stone templet, which receives the shoe of the iron trussed frames of the main roof. The roof is on a pitch of thirty

PLATE XVI

NOWSHERA BARRACKS.

built to accomodate one company



degrees, and is formed of large Grecian tiles set in mortar, over twelve inch square bricks, two inches thick.

The walls of the inner veranda are sixteen feet high from the level of the floor to the bottom of the iron beams. The roof is flat, formed by arching from beam to beam, the underside being plastered, and the upper covered with one inch fine terrace, the spandrils being filled in level.

The walls of the outer veranda are twelve feet nine inches high. The roof being flat, pucka terrace, supported on deodar kurries, scantling 5 × 4 inches, placed nine inches apart.

The main walls are two and a half feet thick up to the inner veranda roof, and two feet above this.

The plinth is three feet in height, and has one off-set of three inches, and the foundation, which is two feet deep, has two off-sets each three inches.

The inner veranda walls are two feet thick up to the outer veranda roof, and one and a half feet above this.

The plinth and foundation have similar off-sets to the main walls.

The outer veranda walls are two feet thick up to the springing of the arches, and one and a half feet above this. The plinth is one foot lower than the interior floors, and the foundation is only one and a half feet deep, with similar off-sets to the other walls.

The masonry of the foundation and plinth is of slate stone and mortar, the latter having equal proportions (by measurement) of stone lime, soorkee, and river sand.

The masonry of the superstructure is throughout of burnt brick and lime cement, in proportions as above.

The whole of the interior of the buildings is plastered with sand plaster, having washed sand and lime, in equal proportions (by measurement.)

The exterior of the whole building is pointed, with exception of the cornices, which are plastered with a cement formed of lime and soorkee, in equal proportions, well beaten and consolidated; two feet at the bottom of the outer walls and the outer face of the plinth are plastered similarly to the cornices.

The whole of the flooring is formed of slate slabs set in mortar, over two courses of bricks laid flat, earth being first filled in and rammed to obtain the necessary height.

The whole of the doors are pannelled, the frames being two inches thick, the windows, where practicable, are hung on the centre so as to open when required.

The punkahs are hung from iron rods at a height of fifteen feet from the floor. For the purpose of ventilation the ridge of the main roof is perforated along its entire length, and in the inner veranda the iron tubular beams are left open at the extremities to admit a current of air through them into the building.

Abstract of Estimate.

		R.	A.	P.
4,939·5	Cubic feet slate stone masonry in foundation and plinth, at Rs. 18 per 100,	8.269	1	9
942·5	Brick-on-edge masonry in plinth, at 20 Rs. per 100,	188	8	0
1,27,190	Cubic feet pucka brick masonry in superstructure, at Rs. 19 per 100,	24,166	1	7
92,00·9	Cubic feet pucka arched masonry, at Rs. 21 per 100,	1,932	3	0
12028	Superficial feet main roofing, at Rs. 40 per 100,	4,811	3	2
11583	Superficial feet inner veranda roofing on iron beams, at Rs. 35 per 100,	4,054	0	10
2751	Superficial feet flat pucka roof of Reading and Sergeant's rooms, at Rs. 50 per 100,	1,375	8	0
13,970	Superficial feet outer veranda roofing, at Rs. 28 per 100,	3,911	9	7
142,306·89	Superficial feet pucka plaster, at Rs. 3-8 per 100,	4,880	11	10
1,18,100	Superficial feet whitewashing, at 8 annas per 100,	590	8	0
60,197	Cubic feet filling in under floors, at 6 annas per 100,	225	11	9
34,161·25	Superficial feet stone flooring, at Rs. 20 per 100,	6,832	4	0
19,880	Superficial feet outside painting, at Rs. 2-4 per 100,	447	4	10
6,919	Superficial feet doors and windows, at Rs. 80 per 100,	5,535	3	2
74	Punkahs, with iron suspension rods, ties, &c., at Rs. 15 each,	1,110	0	0
768	Superficial feet shelves, at 4 annas per foot,	192	0	0
192	Accoutrement pegs, at 3 annas per 100,	36	0	0
90,497	Cubic feet filling in round barrack, at 6 annas per 100,	339	5	10
	Total,	68,997	5	4
	Contingencies, 5 per cent.,	3,449	13	10
	Grand Total,	72,447	3	2

MEMORANDUM.

The cost of the carriage of iron roofing from Lahore to Nowshera is included in the estimate; but the price of the iron work is not known.

Forty-two trussed frames and 184 iron beams are used in each barrack.

The masonry of the cornices is not set down as a separate item, but included in the masonry of the building,

F. S. TAYLOR.

No. XIII.

GOODWYN'S TILED ROOFING.

From Superintending Engineer, Central Provinces, to all Executive Engineers.

Gwalior, 6th December, 1850.

GENTLEMEN,—It being very important that an improvement should take place in both the manufacture of roofing tiles, and the method of tiling, I have the honor to draw your earliest attention to the matter, trusting to a zealous co-operation in the endeavour to effect so very desirable an end. I need scarcely point to the causes which induce me to attempt a reformation in this material, they are, however, briefly these :—

1*stly*. They are not sufficiently substantial to resist the action of winds, and the disturbing propensities of kites and crows, whilst it is a matter of difficulty to repair a broken tile on a roof, without either disarranging or fracturing others, on account of their brittleness and lightness.

2*ndly*. From their small size, they require the intervention of a bamboo frame, tied with string, which, when it begins to decay causes settlement of the tiles and leakage.

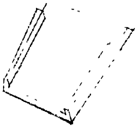
3*rdly*. If laid in mortar, the consumption of that material is far too great in proportion to the surface covered by the tiles, whilst if laid in mud, which is constantly the practice, a nest of white ants is carried up into the roof to destroy the frames and timber; besides, the mud shrinks in drying, and is of no use as a cement.

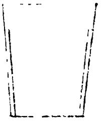
4*thly*. They are so carelessly made, from the fact of the clay not being either properly tempered and kneaded, and the tiles themselves

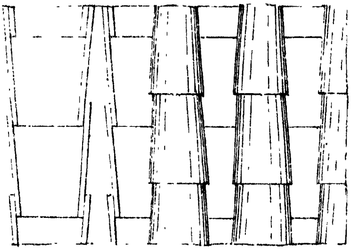
PLATE

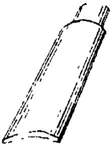
GOODWYN'S TILED ROOFING.

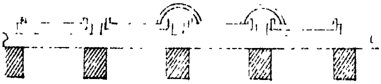
Scale of Feet

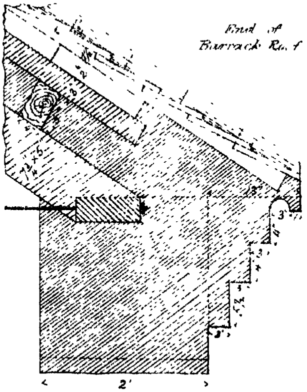


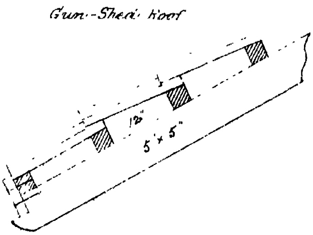












not being properly moulded and formed, that they frequently absorb water and very nearly melt, whilst rain in high winds is driven through every interstice.

Here are surely causes enough for the introduction of a material, which shall be not only serviceable as a permanent covering, but relieve you from the constantly recurring necessity of repairs which, when executed, are flimsy, easily destructible and unsatisfactory.

The kind of tiles that I wish to introduce, is a large and substantial flat tile, with raised edges, the joints between which are covered with a semi-cylindrical tile, precisely such as were in use by the Romans. I have successfully made them both in Calcutta and Lahore, and there is no reason why they should not be generally adopted. The accompanying sketch, will shew the nature of the tiles, and the method of tiling. Being 12 inches wide at the upper end, they are laid either on small rafters placed at 1 foot between centres, or on battens with similar intervals.

For buildings, where a moderate temperature is required, they may be placed over a layer of the common flat tile, 1½ or 2 inches thick, with a thin bed of mortar intervening; but in buildings of less pretension they should be laid alone on the wood-work, with cemented joints. The eaves may be finished off either by upright eave tiles in cement, or wooden plates let into the end of the rafters; for ornamental purposes, by a plain Tuscan cornice, the corona well projecting and undercut to throw off the rain water clear of walls, or by a gutter and simple fascia, where well preserved wood or metal is available.

The clay required for tiles, should be stronger and more tenacious than that required for bricks, *i. e.*, it should not have the same proportion of sand in it, it should be dug sometime before moulded, and all foreign substances likely to destroy the tile when burning, carefully extracted. As a pug-mill is seldom available, the clay should be cut, slashed, turned with phourahs, watered, and left in a heap for some time, covered with brushwood if possible, to prevent its getting too dry. Before moulding it should be kneaded and well tempered, reducing it to a uniform texture. It will be necessary, I think, to use moulds, to form the flat tile, and the freshly moulded tile should be 1⅛ inches thick all over, that it may dry to about 13/16th or ⅞th inches thick. Great care should be observed in the drying; a moderate sun, or (when that is powerful) almost shade being requisite to prevent distortion. They may be burnt occasionally with large bricks, but I think a pottery kiln is better.

H. GOODWYN.

From CAPTAIN J. N. SHARP, *Ex. Engineer, Lahore Division, to* LIEUT.-COLONEL G. B. TREMENHEERE, *Superintending Engineer, Punjab Circle.*

SIR,—I beg to forward you the following report on Colonel Goodwyn's Tiled Roofing, as at present constructed, a copy of which I beg you will be good enough to forward to him agreeably to his request.

DETAIL OF CONSTRUCTION.

Deodar battens 3″ × 2″ are nailed on the purlins at twelve inches from centre to centre, on which are laid twelve inch square tiles, two inches thick, well fitted, cemented at the joints, and pointed underneath; a layer of good mortar about one and a half inches thick is then laid, in which the pan-tiles are well embedded at regulated intervals, which are filled up with mortar, and over them the round tiles carefully fitted and set. The eaves terminate in a masonry cornice, as shown in the figure, and the ridges are covered in with round and flat tiles, expressly made for the purpose; gable ends have been adopted as better suited to this description of tiling; the slope of the roof 28°. After the tiles had been laid, the joints were carefully pointed, and the roofing kept well wetted during its construction and for ten days afterwards by means of watering pots used from the ridge of the building, not in a stream down the roof, but merely sufficient to keep the whole saturated.

(1) WEIGHT OF TILING PER SQUARE FOOT.

One square tile 12″ × 12″ × 2″, - - - - -	19lbs.
One pan-tile. - - - - - - - - - -	6lbs.
One round tile, - - - - - - - - -	4lbs.
One and a half inch of mortar, - - - - - -	12lbs.
Total, -	41lbs.

(2) DETAIL OF LABOR AND MATERIALS PER 100 SQUARE FEET.

		R.	A.	P.
½ Mate mason	@ As. 5	0	2	6
10 Masons, -	„ 4	2	8	0
⅓ Grammie, -	„ 2½	0	0	10
2 Bheestees, -	„ 2½	0	5	0
¼ Carpenter, -	„ 4	0	1	0
½ Mate cooly,	„ 2½	0	1	4
14 Coolies, -	„ 2	1	12	0
1 Coolie, -	„ 1½	0	1	6
Establishment,	-	0	2	6
	Total Rs.	5	2	7

Materials.		R.	A.	P
100 Square tiles,	@ Rs. 25	2	8	0
110 Pan-tiles, 110 Round tiles,	„ 15	3	4	0
25 Maunds of kunkur lime @ Rs. 15 per 100,	-	3	12	0
2½ Stone lime @	„ 1	2	8	0
Scaffolding, &c.,	-	0	6	0
Total Rs.	-	12	10	0

The labor appears high, but so is all labor at this station; wages are high and very little work done. The tiles are exceedingly well made by contract at the above rates, paid for as counted in the building, allowing ten per cent. for breakage; the kunkur lime is of very inferior quality, and will admit of no admixture with pounded bricks or gravel, and for want of mortar-mills to grind it, is only sifted, the refuse used on other works.

Under ordinary circumstances this tiling would not cost more than two-thirds of the above.

COMPARISON OF TEMPERATURE OF A BARRACK WITH THIS ROOF, AND WITH ONE OF SMALL TILES OVER SIX INCHES OF GRASS.

European Infantry.	Barrack roof, small tiles over six inches grass; 24 feet high to tie-rod. Barrack roof, Colonel Goodwyn's tiles; 24 feet to tie-rod. Quarter-Guard, Colonel Goodwyn's tiles; 17 feet to tie-rod.
Artillery.	Canteen, Colonel Goodwyn's; 20 feet to tie-rod.

The experiment was made from the 12th July, to the 12th October 1853, khus-khus tatees having been in use until the 30th June, during which period it was not considered adviseable to make the experiment. The thermometers were all similarly placed, six feet above the floor and read off at mid-day, when the gun fired; the thermometers were first compared, and the readings reduced accordingly. It appeared from this experiment that there is really no difference of temperature between the tiled and grass, and tiled roof with 24 feet elevation, and that it is not advisable to have Colonel Goodwyn's tiled roof less than twenty feet above the floor, if to be occupied by Europeans, and that a ceiling cloth should be used to cut off the heat of the roof in small buildings, as Staff-Sergeant's bungalows. In all buildings that close, there should be ridge ventilators; and in those occupied by Europeans, there should, I think, be more than are at present in use, with six inches clear opening on each side of the ridge pole.

CONCLUDING REMARKS.

The earliest of Colonel Goodwyn's tiled roof constructed here, has been finished nearly two years, and has never leaked or needed repairs, and apparently will not require anything beyond pointing and re-placing of broken tiles for years.

It is probable that with the heavy rains of Bengal, the roof might become saturated throughout, and a few drops percolate through, yet this would altogether be avoided by glazing the tiles; but if well constructed (and it requires the very best materials and careful labor) I do not think a better roof could be contrived for Upper India, being free from breakage, promising great durability, and with some trouble made anywhere.

It appears to me essential that this roof should terminate at the eave with a masonry cornice, and not with boards; and tiles 12″ × 18″ × 2″ would I think be better than 12 inches square.

The pan and round tiles if made three-quarter inches thick, when burnt, and nailed on to battens, make an excellent roof for ordinary purposes of godowns, gun-sheds, stables, &c, &c.

J. N. SHARP.

No. XIV.

ON THE STABILITY OF ARCHES, WITH REFERENCE TO THEIR FORM.

By Archdeacon J. H. PRATT.

To the Editor of Professional Papers on Indian Engineering.

SIR,—Having been asked to give an opinion, on theoretical grounds, regarding the stability of a bridge about to be erected in this country, I calculated some formulæ, which, as I have not seen the subject treated in this way anywhere else, I think may be of use to some of your readers.

The stability of an arch may be endangered from three causes; 1st, the pressure at certain points may be such as to crush the materials; 2nd, the friction of the voussoirs against one another may not, in one or more parts, be sufficient to prevent their sliding one past another, under great pressure; 3rd, the form of the arch may be such that when a load comes upon it the arch may become broken, by the voussoirs opening in the intrados and extrados.

It is this last case which I consider in the present paper.

In some cases Engineers appear to consider that an arch will be stable if it is capable of bearing the greatest load which is ever likely to come upon it, *placed simultaneously on every part of the road-way;* and calculations are gone into, based sometimes upon the law of the inverted catenary, to ascertain how deep the voussoirs ought to be and how the materials above the arch ought to be arranged, so as to preserve all in equilibrium, when a load is spread over the whole road-way uniformly. This might be very well if the arch were merely an architectural structure, to bear always one and the same weight and no other! But if an arch is to do duty in a bridge, it is to be subject to unequal pressure upon its several parts as loads pass over it; and an arch which might stand for ever in the former case, might soon fall to ruin in the latter. In the following calculation, therefore, I suppose a load placed over the arch, *first* on one side, and *secondly* over the centre; and the course I adopt is this; I imagine the arch to be broken into portions and slightly forced out of its position and held so, and then left to itself. If the parts collapse, I consider that the arch, as regards its form, is stable: if the parts do not collapse when left to themselves the arch is unstable and dangerous. With this explanation the following diagram speaks for itself.

Fig. 1.

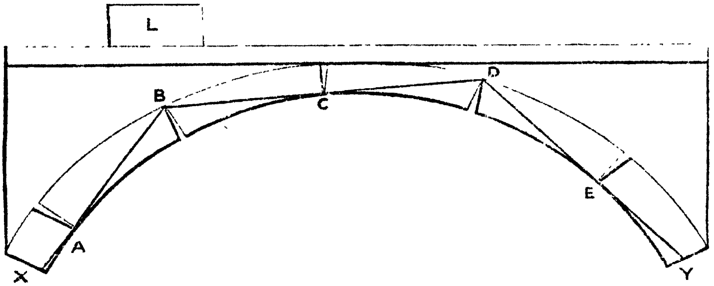
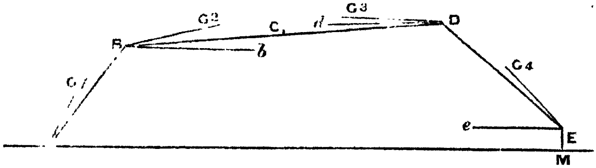


Fig. 2.



$\angle$ BAM $= \alpha_1$, $\angle$ CB$b = \alpha_2$, $\angle$ CD$d = \alpha_3$, $\angle$ DE$e = \alpha_4$,
$\angle$ G$_1$AB $= \beta_1$, $\angle$ G$_2$BC $= \beta_2$, $\angle$ G$_3$DC $= \beta_3$. $\angle$ G$_4$E$e = \beta_4$,
AB $= a_1$, BC $= a_2$, CD $= a_3$, DE $= a_4$, AM $= m$, ME $= n$,
AG$_1$ $= b_1$, BG$_2$ $= b_2$, DG$_3$ $= b_3$, EG$_4$ $= b_4$.

h_1, H$_1$, h_2, H$_2$, h_3, H$_3$, h_4, H$_4$, are the lengths of the projections of AG$_1$ AB, BG$_2$, BC, DG$_3$, DC, EG$_4$, ED upon the horizontal line AM.

1. Suppose a load, L (*Fig.* 1,) to be placed on the bridge over the arch, and not in the centre. B is the point of the extrados under the middle of the load. Draw BAX, BCD, DEY tangents to the intrados. Imagine the arch at the points A, B, C, D, E, to be divided into four parts, and to be forcibly held in the position shown in the diagram, in which the arch is slightly open at joints through those points. If the equilibrium of the arch is stable, the parts will fall back into their places when left to themselves; if unstable, the arch will fall.

The manner in which I shall apply this principle is as follows. I shall find the algebraical expression for the height of the centre of gravity of the four parts into which the arch is divided above a fixed horizontal line: and shall ascertain whether a very slight change in the positions of those parts will *raise* or *depress* their centre of gravity. In the first case the arch is stable, because the centre of gravity (which will always descend) will descend and bring the parts together again: in the second case, the arch is unstable, because the centre of gravity will descend and separate the parts more than they were and the whole will fall. The following is the calculation:—

Let W_1, W_2, W_3, W_4 be the weights of these four portions of the arch, including the total load each carries (not omitting L). G_1, G_2, G_3, G_4 (in *Fig.* 2) the centres where these weights may be supposed to be collected. Let V be the height of the centre of gravity of these four weights above the horizontal AM. Then

$$(W_1 + W_2 + W_3 + W_4)\,V = W_1 b_1 \sin(\alpha_1 + \beta_1)$$
$$+ W_2\big(a_1 \sin\alpha_1 + b_2 \sin(\alpha_2 + \beta_2)\big) + W_3\big(n + a_4 \sin\alpha_4 + b_3 \sin(\beta_3 - \alpha_3)\big)$$
$$+ W_4(n + b_4 \sin\alpha_4).$$

Also the angles are connected by the following relations (*N.B.* $\alpha_3 = \alpha_2$, because BC and CD are in the same straight line: but I shall at first reason on the more general supposition that they are not necessarily so),

$$a_1 \cos\alpha_1 + a_2 \cos\alpha_2 + a_3 \cos\alpha_3 + a_4 \cos\alpha_4 = m,$$
$$a_1 \sin\alpha_1 + a_2 \sin\alpha_2 + a_3 \sin\alpha_3 - a_4 \sin\alpha_4 = n.$$

Differentiating these with respect to the angles, which alter when the arch is slightly moved out of its position,

$$a_1 \sin\alpha_1\,\delta\alpha_1 + a_2 \sin\alpha_2\,\delta\alpha_2 + a_3 \sin\alpha_3\,\delta\alpha_3 + a_4 \sin\alpha_4\,\delta\alpha_4 = 0,$$
$$a_1 \cos\alpha_1\,\delta\alpha_1 + a_2 \cos\alpha_2\,\delta\alpha_2 + a_3 \cos\alpha_3\,\delta\alpha_3 - a_4 \cos\alpha_4\,\delta\alpha_4 = 0.$$

I have kept α_2 and α_3 general, that I might obtain these equations by differentiation. Now consider them equal, and obtain $\delta\alpha_3$ and $\delta\alpha_4$ in terms of $\delta\alpha_1$ and $\delta\alpha_2$ by these equations. Multiply the first by $\cos\alpha_2$ or $\cos\alpha_3$, and the second by $\sin\alpha_2$ or $\sin\alpha_3$, and subtract,

$$\therefore\ a_1 \sin(\alpha_1 - \alpha_2)\,\delta\alpha_1 + a_4 \sin(\alpha_3 + \alpha_4)\,\delta\alpha_4 = 0,$$

$$\therefore\ \delta\alpha_4 = -\frac{a_1}{a_4}\frac{\sin(\alpha_1 - \alpha_2)}{\sin(\alpha_3 + \alpha_4)}\,\delta\alpha_1.$$

Again, multiply the two equations by $\cos\alpha_4$, $\sin\alpha_4$, and add; then

$$a_1 \sin(\alpha_1 + \alpha_4)\,\delta\alpha_1 + (a_2\,\delta\alpha_2 + a_3\,\delta\alpha_3)\sin(\alpha_3 + \alpha_4) = 0,$$

$$\therefore\ \delta\alpha_3 = -\frac{a_2}{a_3}\,\delta\alpha_2 - \frac{a_1}{a_3}\frac{\sin(\alpha_1 + \alpha_4)}{\sin(\alpha_3 + \alpha_4)}\,\delta\alpha_1.$$

Now differentiate the expression for V, observing that $\beta_1 \ldots$ are constant, and substitute the values of $\delta\alpha_4$ and $\delta\alpha_3$; also substitute h_1 H_1 ... which have been explained above, and are $b_1 \cos(\alpha_1 + \beta_1 = h_1)$ $a_1 \cos\alpha_1 = H_1, \ldots$

$$\therefore\ (W_1 + W_2 + W_3 + W_4)\,\delta V$$

$$= W_1 h_1 \delta\alpha_1 + W_2 (H_1 \delta\alpha_1 + h_2 \delta\alpha_2) + W_3 (H_4 \delta\alpha_4 - h_3 \delta\alpha_3) + W_4 h_4 \delta\alpha_4$$

$$= \delta\alpha_1 \left\{ W_1 h_1 + W_2 H_1 - (W_4 h_4 + W_3 H_4) \frac{a_1}{a_4}\frac{\sin(\alpha_1 - \alpha_2)}{\sin(\alpha_3 + \alpha_4)} \right.$$
$$\left. + W_3 h_3 \frac{a_1}{a_3}\frac{\sin(\alpha_1 + \alpha_4)}{\sin(\alpha_3 + \alpha_4)} \right\} + \delta\alpha_2 \left\{ W_2 h_2 + W_3 h_3 \frac{a_2}{a_3} \right\}.$$

Suppose that AB and ED are produced to meet in the point F (not drawn in the diagram), and that the angles of the triangle FBD are called F, B, D. Then the above formula becomes

$$(W_1 + W_2 + W_3 + W_4)\,\delta V$$

$$= \delta\alpha_1 \left\{ W_1 h_1 + W_2 H_1 - (W_4 h_4 + W_3 H_4)\frac{a_1}{a_4}\frac{\sin B}{\sin D} + W_3 h_3 \frac{a_1}{a_3}\frac{\sin F}{\sin D} \right\}$$
$$+ \delta\alpha_2 \left\{ W_2 h_2 + W_3 h_3 \frac{a_2}{a_3} \right\}.$$

$\delta\alpha_1$ and $\delta\alpha_2$ are independent and arbitrary variations of α_1 and α_2: $\delta\alpha_1$ cannot be positive and $\delta\alpha_2$ cannot be negative, owing to the structure of the arch and the way in which the openings take place. Take the most unfavourable case, where $\delta\alpha_2 = 0$; that is, suppose the point C slides slightly to the right, along CD, Then δV, or the variation of height of the centre of gravity of the four weights (measured upwards), will be positive or negative according as

$$W_1 \frac{h_1}{a_1} + W_2 \frac{H_1}{a_1} + W_3 \frac{h_3}{a_3}\frac{\sin F}{\sin D} \text{ is } < \text{ or } > \left(W_4 \frac{h_4}{a_1} + W_3 \frac{H_4}{a_4} \right) \frac{\sin B}{\sin D}.$$

In the first case the arch will be stable, because the slight displacement raises the centre of gravity; and as this will fall, the openings will close up again when the arch is left to itself. In the latter case the centre of gravity descends, owing to the displacement of the parts of the arch, and will go on descending when the arch is left to itself, and therefore the arch will fall.

The application of these principles to a particular case is as follows:— When any design of an arch is determined upon, suppose different portions of the load L, and find all the quantities involved in the above formula by construction and measurement by a scale; and the character of the proposed arch for stability will be at once determined.

Example.—Suppose W_1, W_2, W_3, W_4 are as 10, 6, 5, 9 *independently of* L, and sin B = sin 55° = 0·819, sin D = sin 45° = 0·707, sin F = sin 80° = 0 985 : also suppose that

$$\frac{h_1}{a_1} = \frac{1}{6}, \frac{H_1}{a_1} = \frac{1}{2}, \frac{h_3}{a_3} = \frac{3}{7}, \frac{h_4}{a_4} = \frac{2}{5}, \frac{H_4}{a_4} = \frac{9}{14}.$$

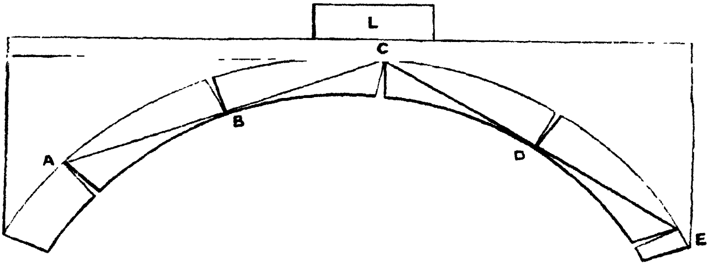
Putting these in the above formula of comparison, the values of the two sides will come out 7·65 and 7·89. The first is less than the second, and therefore the arch would be in itself stable. Now introduce L, and suppose the centre of gravity to be over B, and half added to W_1 and half to W_2. Then the two sides of the comparison will become

$$7·65 + 0·75 \text{ L and } 7·89,$$

and therefore the arch will be at its limit between stability and instability when these are just equal to each other, that is, when L = 0·32, or about $\frac{1}{64}$th part of the weight of the whole bridge. Practical men must decide whether this would be safe.

II. Suppose, in the next place, that the load L is near the crown of the arch, and that the arch is forcibly held in the position marked in *Fig.* 3.

Fig. 3.



By reasoning precisely as before, and observing that in this case = a_1 and $a_3 = a_4$, we obtain —

$$a_1 \cos \alpha_1 + a_2 \cos \alpha_2 + a_3 \cos \alpha_3 + a_4 \cos \alpha_4 = \text{constant},$$
$$a_1 \sin \alpha_1 + a_2 \sin \alpha_2 - a_3 \sin \alpha_3 - a_4 \sin \alpha_4 = \text{constant};$$
$$\therefore a_1 \sin \alpha_1 \, \delta\alpha_1 + a_2 \sin \alpha_2 \, \delta\alpha_2 + a_2 \sin \alpha_3 \, \delta\alpha_3 + a_4 \sin \alpha_4 \, \delta\alpha_4 = 0,$$
$$a_1 \cos \alpha_1 \, \delta\alpha_1 + a_2 \cos \alpha_2 \, \delta\alpha_2 - a_3 \cos \alpha_3 \, \delta\alpha_3 - a_4 \cos \alpha_4 \, \delta\alpha_4 = 0;$$

which, since $\alpha_2 = \alpha_1$, $\alpha_3 = \alpha_4$, give

$$a_1 \, \delta\alpha_1 + a_2 \, \delta\alpha_2 = 0, \quad a_3 \, \delta\alpha_3 + a_4 \, \delta\alpha_4 = 0.$$

Also,

$$(W_1 + W_2 + W_3 + W_4)\,V$$
$$= W_1 b_1 \sin(\alpha_1 + \beta_1) + W_2 \big(a_1 \sin \alpha_1 + b_2 \sin(\alpha_2 + \beta_2)\big)$$
$$+ W_3 \big(a_4 \sin \alpha_4 + b_3 \sin(\alpha_3 + \beta_3)\big) + W_4 b_4 \sin(\alpha_4 + \beta_4) + \text{constant};$$
$$\therefore (W_1 + W_2 + W_3 + W_4)\,\delta V$$
$$= \delta\alpha_1 \left(W_1 h_1 + W_2 H_1 - W_2 h_2 \frac{a_1}{a_2}\right) + \delta\alpha_4 \left(W_3 H_4 - W_3 h_3 \frac{a_4}{a_3} + W_4 h_4\right),$$

$\delta\alpha_1$ and $\delta\alpha_4$ must both be positive. Hence the equilibrium will be stable if

$W_1 \frac{h_1}{a_1} + W_2 \frac{H_1}{a_1}$ be not $<$ $W_2 \frac{h_2}{a_2}$, and $W_3 \frac{H_4}{a_4} + W_4 \frac{h_4}{a_4}$ not $<$ $W_3 \frac{h_3}{a_3}$.

If the numerical values of the example already given are substituted, the result shows, that the arch would be stable in this position of the load, however great the load is.

If the two sides of the formula of comparison are, in any example of an arch, *very nearly* equal, this would show that the parts are very nearly balanced; the line of pressure, when the arch is not divided, would in this case pass very near the intrados (C in *Fig.* 1, B and D in *Fig.* 3). The materials at those points would be under a great strain as a heavy load passed over, and portions might be chipped off. In this way an arch, although its data might, (though only just) satisfy the conditions of stability, would really be unsafe. There should be a decided difference between the numerical value of the two sides of the formula of comparison to ensure stability.

J. H. P.

No. XV.

PUBLIC WORKS IN MYSORE.

Report by MAJOR R. H. SANKEY, R.E., *Assistant to the Chief Engineer, to the Officiating Chief Engineer in Mysore, of two tours of inspection made by him in that Province.*

Bangalore, 30th May, 1863.

HAVING been directed by the Government of India to furnish a digest of the report on my inspection tour undertaken in November, and further being requested by the Commissioner to add some particulars connected with my examination of works in another portion of the Province during last month, I have the honor to offer the following observations, and at the outset beg to state briefly the extent and objects of the journeys in question.

On my November tour, while proceeding along the Mysore road, I inspected chiefly the Anicut now constructing across the Shumsha river at Muddoor, the site of the proposed large Soolakerray tank, and also the position for an aqueduct over the Lokani river near Seringapatam. Continuing my route through Yelwall I turned north and examined the proposed new line of road leading direct from Mysore to Hassan, with the sites for the bridges, which may eventually span the Cauvery and Hemavutty rivers at Yedtora and Nursipoor.

Proceeding thence to Arculgode and Coodlipett, I was enabled to see nearly the whole of the road now under construction between that place and Mercara in Coorg, and subsequently the Munzerabad ghaut; the site of the proposed bridge over the Hemavutty at Saklaspoor; the road leading along the western ghauts to Moodgherry; the Boond ghaut (now under construction); the road through Chickmuggloor to Santawara, and the top of the Bababooden mountains; the proposed new ghaut leading down from Santawara to Lingadhully, and the new road from Terrikerray to Adjumpore.

From the latter place, striking across the valley of the Huggary by Hossdroog, I reached the Mauri Cunavai, and subsequently proceeding to Herrioor, returned by the main road to Bangalore. The whole of this route, which can be easily traced on the Map, is about 600 miles in length, and occupied the whole of the month of November.

During the last week of April, I inspected the new Railway feeders to the east of Bangalore, and then proceeding along the new Cuddapah road, as far as the frontier at Ralpand, returned to Chintomonipett; and rode over the proposed line from that place *viâ* Sandly to Bagapully, near the Madras frontier, on the Ghooty road. From this point striking across country, I passed through the mountainous tract at Goodybundah and thence to Goreebednore, visiting *en route* the fine tank at Wottadahoshully.

From Goreebednore I returned south to Dadaballapoor, examining the proposed line of road between these two places; and subsequently, after inspecting two ghauts north of Nundidroog, and some short roads now under construction about that place, returned to Bangalore.

Taken together these tours extended over 900 miles, and enabled me to see most of the important works either under execution or proposed. Of these, I shall now endeavor to explain concisely the most important features, adding some observations of a general nature connected with the working of the department, &c.

The Muddoor Dam.—The Muddoor dam, which was the first work inspected by me, and the most important irrigation work hitherto undertaken in the Province, lies eight miles north-west of the town of the same name, half way between Bangalore and Mysore. The present work was undertaken with a view of re-placing the old native Anicut across the Shumsha river, which from defective construction (core, *loose stone and earth;* facing *brick;* top long stones packed dry on end; foundation *rock;* length 300 yards; average height thirteen feet; breadth forty to sixty feet) leaked a great deal, gave perpetual trouble, and was liable to be carried away by the first high flood. *Fig.* 1.

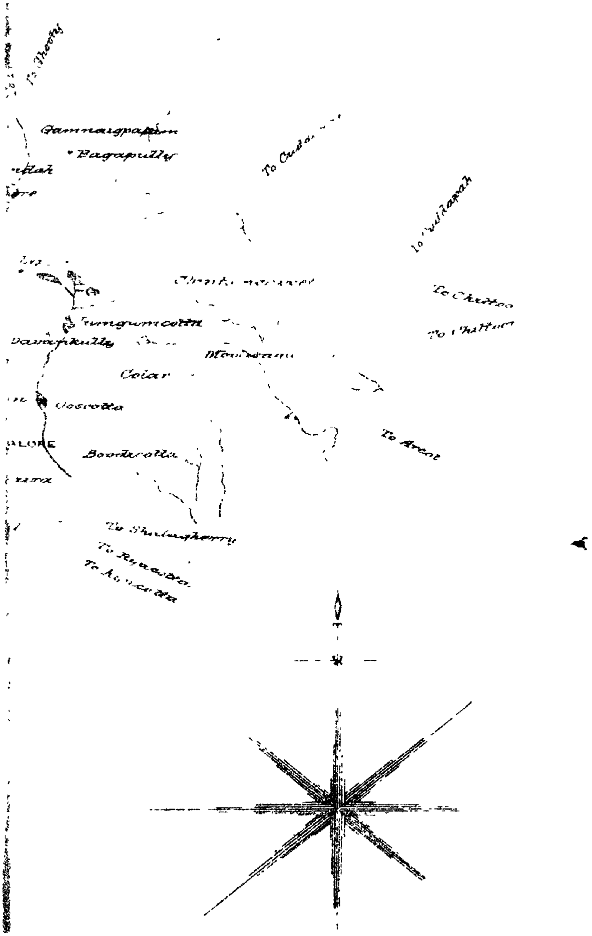
The new Anicut *Fig.* 2 is being constructed immediately in rear of the old one, the material of which is being turned to account. It is only ten feet broad at the top, which is formed of cut stone laid on brick in chunam;

PLATE XVIII.

SKETCH MAP

of

Mysore and Coorg.



facing brick in chunam; core, boulders and small stone grouted in; backing, cut stone in steps.

The channel which leads off from a head or regulating sluice at the west flank of the work is eleven miles long, passes through two tanks above three others, and from the quantity of water which will now be available a new tank is to be constructed, and the tail of the channel led to the large Cusbah tank at Muddoor. From the great value of land thus brought under irrigation, the returns on the outlay are calculated at 16 per cent., and will probably exceed this when the works are completed and the whole of the water utilised.

When inspected by me, about 150 feet of the dam had been carried to very nearly the full height, and although thus exposed with one end, *en l'air*, it had successfully withstood the rush of some severe floods which had passed over it during the monsoon. Nothing could be sounder or more satisfactory than this portion of the work.

This work, the idea of which originated with Captain Johnson, the Executive Engineer, will doubtless, when completed, prove a great success, and this will be the more satisfactory as the strength of the department has been severely tried by its execution. When commenced there appeared no probability of obtaining properly qualified superintendence, and the country afforded no labor, carts or cattle; everything almost had to be imported. Floods came down the river, material was destroyed by rain, cholera broke out among the workpeople, and the superintendence has been very inefficient, yet in spite of everything, the work has advanced, and though again and again delayed by unseasonable and almost unprecedented rain, will, I hope, be sufficiently advanced this season to make good our pledge of bringing nearly all the tract between the channel and the river under irrigation.

Soolakerray Tank.—A few miles past Muddoor, the new Seevasamoodrum road takes off in a southerly direction, and the work of formation is progressing satisfactorily; it is not, however, bridged as yet. After proceeding some distance along this road and turning off to the village of Sadallahully (shewn in the Trigonometrical Survey), a view is obtained of the rich valley, which will probably at no great distance of time be brought under the effects of irrigation from the proposed large Soolakerray tank, the formation of which has long been contemplated by the Mysore Engineers.

There is an old native bund now existing across the valley 11 or 1,200 yards long, and varying in height from twenty to forty feet. Gaps were left in the bund for the sluices, the whole front faced by magnificent blocks of stone, and the only remaining work was the construction of sluices and waste weirs, with the filling in of the centre part of bund, through which the river now flows in a bed some seventy feet below the crest of the bund. Possibly, the difficulty of filling in this great central gap intimidated the original native projectors of the work, for it was evidently never finished, or the tank brought into action.

The fall of the river is no less than eleven feet per mile, and the flood section 200 feet wide by fifteen feet in depth, and all are agreed that the supply of water would be most abundant. Captain Johnson had a survey taken and levels run for the high level channels, and had framed an estimate, amounting to two lakhs, for raising the present bund twelve feet, and otherwise completing the work. The whole project is certainly well worthy of consideration, but being under the impression that in the absence of reliable data regarding the supply of water, it would be undesirable to propose so large an extension of the work, I recommended that after further investigation an estimate should be framed, which should provide for little more than the completion of the original native work, as we would thus, it appeared to me, insure large profits at a minimum cost.

This suggestion is now being acted upon, and there is every reason to believe that a detailed estimate will be ready for entry in the next budget.

The Lokani Aqueduct.—After proceeding about eight miles beyond Mundiem, on the Mysore road, and turning off to the military station known as the French Rocks (Erode on the Map), the Lokani river is met about two miles from the station, and just at this point is crossed by the great Chickdavasagur irrigation channel, which, taken off from an Anicut several miles up the Cauvery river, here diverges nearly five miles from the stream and converts the whole of the intervening ground into a sheet of wet cultivation—the finest in the Province.

The channel has a total length of seventy-two miles, and produces a yearly revenue of rupees 69,000; its maintenance in a thorough state of efficiency is therefore of the greatest importance to the State; yet, considering that the canal by reason of its length, crosses a great amount of drainage from the upper lands, this is necessarily a matter of considerable difficulty, and especially is this the case at the point abovementioned.

PLATE XIX

PUBLIC WORKS IN MYSORE

Fig 1

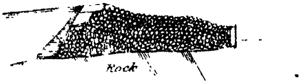


Fig 2

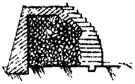


Fig 3

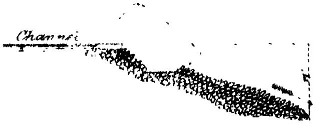
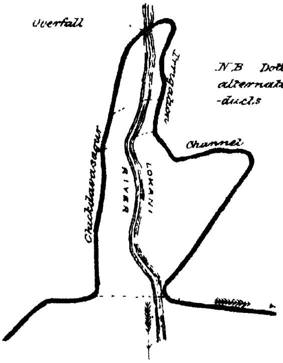


Fig 4



N.B. Dotted lines shew the alternative sites for aqueducts

Fig: 5
Section thro' roadway & aqueduct

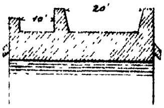
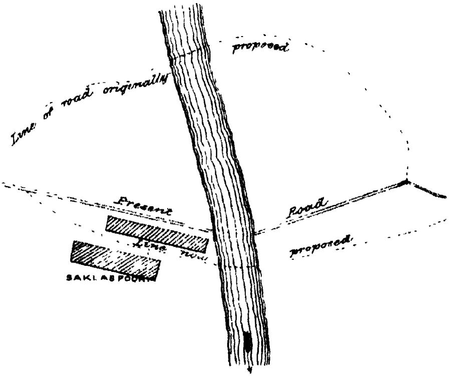


Fig 6



The channel is carried across the bed of the Lokani by means of an old native weir *Figs.* 3 and 4 (200 feet along, seventeen or eighteen feet high, composed of large blocks of stone packed on end at the surface, and abutting against rock at foot), and the river floods find vent by rushing over this into the natural channel below. At such times, however, so much silt is brought down into the irrigation canal on either side, that frequently at the most critical period for the cultivation, water is prevented passing down for ten days or a fortnight. After violent floods, moreover, the weir itself often needs much repair. It is, therefore, most desirable on all accounts that the difficulties at this point should be overcome, by doing away with the weir altogether, and carrying the canal over the Lokani at some site lower down by means of an aqueduct.

I was enabled to select three alternative sites for the required work with Captain Johnson; all good in their way. Each has its peculiar features, which it is unnecessary to detail here, and as the adoption of one or other must depend mainly on the amount of estimate now under preparation, it will suffice to say that the work will probably be entered in the next budget.

There is the most distressing waste of water all along the many fine channels led off from the Cauvery and Hemavutty rivers, and it will need years of the most persevering efforts to bring the matter at all into a satisfactory state. A newly constituted establishment has been placed lately under the revenue authorities for general purposes of conservation, and with their aid and the steady correction of such defective points as that abovementioned, much will be effected in time. Valuable as these channels are now, they would become infinitely more so under proper regulation, as not only could their length be greatly increased and much more land brought under irrigation, but by securing a constant supply of water throughout the year, the area of such highly remunerative crops, as sugar-cane, mulberry, &c., could be vastly increased. The subject is of the highest importance, but as it is also an intricate one, I can do no more than allude to it here.

I may now advert to the condition of the communications in this part of the country. Although only little more than half a century has passed since Buchanan reported, that the traffic was confined to pack bullocks and donkeys, a net work of imperial roads, provincial and district, now covers the province, and this is being further completed by Talook roads either under execution or projected. As the Map shews the present position of matters, much better than could be described, I shall confine myself to observations regarding one or two missing links in the chain of communications, investigations connected with which formed one object of my tour.

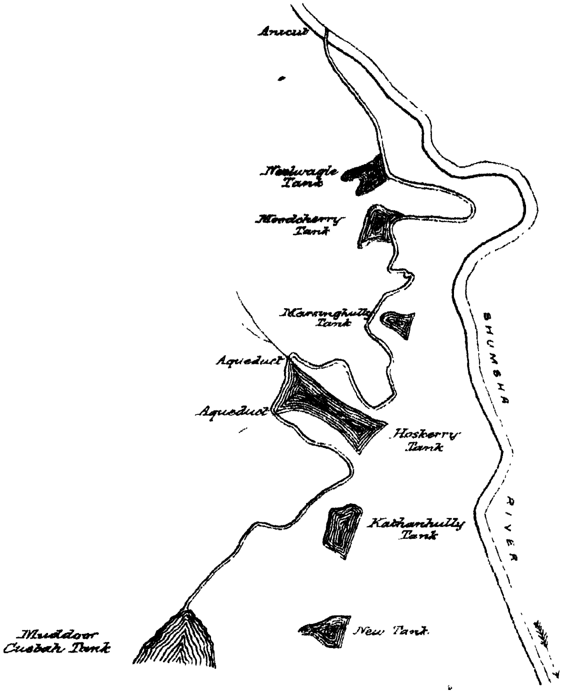
Mysore and Hassan Road.—The chief of these is between Mysore and Hassan, the latter place (or rather perhaps Nursipoor) being one of the great trade centres on the east of the ghauts, Chickmuggloor in Nuggur being the northernmost. In proceeding now from Mysore to Hassan the road after passing the Wellesley bridge at Seringapatam takes north as far as Chewroypatam, where turning at right angles to the west, Hassan is reached after a circuitous route of sixty-nine miles. It will be observed, moreover, that while thus lengthening the distance very considerably, it leaves the whole of the rich country on the right bank of the Hemavutty altogether cut off from communication with the main arteries of the province. This defect it has long been thought desirable to remedy, and efforts have been made through the means afforded by the plough tax fund, to establish a direct road which shall lead from Mysore through Yedtora and Nursipoor to Hassan.

The first link in the line, viz., from Mysore to Yelwall, has long been a second class road, and a short plough tax or fourth class road is being worked out between Yelwall and Yedtora. After this there occurs a gap to within ten miles of Nursipoor, where again a fourth class road is under execution. A rather indifferent third class communication joins Nursipoor and Hassan. My attention was directed to the establishment of a properly bridged third class road from end to end, and an estimate with this object is now being framed.

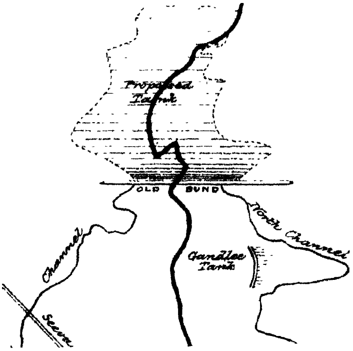
The total length of the road will be fifty-nine miles, and a bridge will eventually have to be constructed over the Cauvery at Yedtora and the Hemavutty at Nursipoor, but if proper ferry boats be substituted for the present primitive basket boats, the expense of bridges need not be immediately incurred.

In addition to these rivers the only one of importance which crosses the proposed road is the Lutchmanteerth, but very opportunely an old and useless aqueduct spans the stream at a very good part for the road, and this will readily turn into a bridge. It may be mentioned that this aqueduct is in connection with a channel taken off from the Cauvery below

PUBLIC WORKS IN MYSORE.



The Soolakerray Tank.



Yedtora, and formed part of a gigantic project, undertaken by the celebrated Dewan Pooneah, for supplying the town of Mysore with Cauvery water. Alongside, and forming part of the work, is a roadway ten feet wide, so that by simply throwing down the wall separating this from the aqueduct portion, a fine road will be at once formed of thirty feet in clear width. *Fig.* 5.

When in the process of time it may become desirable to bridge the Cauvery and Hemavutty rivers, no difficulty will be experienced, as the banks (each about 400 feet apart) are high and the beds consist throughout of rock. The only precaution required will be with reference to the provision of sufficient waterway for extraordinary floods, one of which I find occurred in 1822, and rose to a considerable height, twenty-two feet at Yedtora, twenty-eight feet at Nursipoor.

The construction of the road in all other respects will prove neither difficult nor expensive, both the soil and gradients being favorable throughout, and the amount of drainage to be provided for small.

Mercara and Coadlipett Road.—The next link of importance which it is desirable to complete is that leading direct from Mercara in Coorg, *viâ* Coadlipett to Munzerabad, the great centre for coffee plantation in this part of the province. Between Munzerabad and Coadlipett there has been for some years a bridged road, and for the last two years, work has been in progress on the forty-three miles of road between Mercara and Coadlipett. At the period of my inspection my baggage cart got easily over the eighteen miles between Coadlipett and Somwarpett, and it is expected that the whole amount now remaining to be executed (about five miles) should be worked through in a year. Though carts will thus soon be enabled in favorable weather to proceed with produce from end to end, it must not, however, be understood that the road will be nearly complete, as the communication so far is sustained by means of log bridges over all nullahs, which must give place to others of a permanent description; and further, as the road itself will have to be widened, the surface corrected, and three bridges built, one over the Choranhully (one span of fifty feet), another over the Mahadapoorhully (two spans of fifty feet), and a third over the Huttee river (three spans of fifty feet.)

In this part of Coorg there are several old native tracks leading over hill and dale to the marts of Soobramany, &c., through Somavarsunttay and Frasepett (Kooshalnuggur of the Map), but as these climb up the steep sides of mountains and through dense forests wholly regardless of gradients, the traffic has hitherto necessarily been confined to pack cattle. The road, however, now being constructed, though in a few places rather steep, (*i. e.* having gradients as high as one in twenty,) will allow of fully laden carts using it, and it will doubtless be followed in time by many other roads opening up the most valuable sites for coffee plantations, of which there would appear to be scarcely any limit.

The estimate first framed for the work, rupees 20,000, as may be imagined, will prove wholly inadequate. A correct survey with full details, &c., will, however, be shortly in the hands of Government, the Assistant Engineer in charge, Mr. Stoddard, having now been long engaged upon it. Estimates for the three bridges abovementioned were submitted last year, they were to be timber trusses, masonry being thought too expensive in consequence of the great distance from which lime has to be procured (none is to be found in any portion of the Mysore ghauts) and the difficulty of procuring bricklayers. If we could get Messrs. Knight and Company, to tender for Iron Lattice bridges in lieu of the proposed timber ones, the result would undoubtedly be much more satisfactory.

The Saklaspore Bridge.—The next work of importance which I had an opportunity of inspecting, was the proposed bridge over the Hemavutty at Saklaspore, the head of the Munzerabad ghaut. The original estimate for this work provided for six timber trussed spans of sixty feet each, amounted to rupees 98,117, but this has been in a measure set aside by a proposal, now before Government, to substitute for it a bridge consisting of three Iron Lattice spans of 120 feet each, and it is hoped the matter will receive favorable consideration.

My attention was simply directed to the choice of a proper site for the work, the one originally selected lying some way north of the town, and necessitating long embanked approaches. I am quite satisfied that the bridge may most advantageously be placed just below the present ferry, and in the direct line leading through the town of Saklaspore. The river at this point is exceedingly straight for half a mile up and down stream, and there being but little embanking, and no provision required for lateral drainage, from 15 to 17,000 rupees may be saved on the estimate. *Fig.* 6.

The Kempakull Bridge.—Regarding the Kempakull bridge at the foot of the ghaut, and the ghaut road itself, little need now be said, as both will form the subject of special estimate before long. It may, however, be observed that the climate at the foot of the ghaut is so unhealthly, that it appears almost hopeless to assign either reliable time or rates for the execution of any work there; and, consequently, with reference to the bridge in question, it would seem to be the wisest policy to have it constructed in the most rapid and efficient manner, *i. e.*, by employing Iron Lattice trusses. At present there is an old timber structure which serves to keep up the communication, enabling the coffee planters, whose estates spread far and wide over the head of the ghaut, to send their produce by cart to Mangalore, instead of by pack bullocks, which latter method entails the greatest inconvenience with reference to sorting the different classes of berries at the port for the European market.

The Boond Ghaut.—The next work worthy of consideration is the so called Boond (Coffee) ghaut, situated twenty-four miles north of Munzerabad. It has been in hand for seven years, and last year an estimate amounting to rupees 34,682 was sanctioned for opening it out for cart traffic. When completed, it should allow the coffee of the estates lying about the Bababooden hills (the oldest plantations in South India) being conveyed direct to Mangalore. Much of the Munzerabad coffee may also eventually follow the same route. It is quite possible that the designation assigned to this ghaut has lost somewhat of its distinctive significance, since the rise of Munzerabad and Coorg as centres of coffee production, but in addition to the valuable estates about the Bababoodens, there is an almost boundless tract of country lying northward between the Boond and Agoombee ghauts, which, when opened up by roads, will probably restore the perponderance to this line, and make it the most frequented on the Western Ghauts.

The work is so important in itself, and of such a peculiar character, that I make no excuse for giving some further details connected with it, although I understand my full report has already been submitted to Government.

Kotegar, which is the recognised head of the ghaut, is little more than an open piece of ground favorably placed for a bazar and bullock encampment. A small village now exists there, and the place is to a certain extent sheltered from the monsoon by the hills which crown the submit of the ghaut, and cluster round the pass through which the road is carried.

Leaving Kotegar and passing round a thickly wooded knoll to the right, the side cutting being very heavy at this portion, the road descends with an easy gradient to the so-called Custom House bridge, at which point the central stream of the valley is crossed.

A little in advance of this point the whole valley bursts on the view in a magnificent panorama. On either side the mountains, which are for the most part covered by grass, with deep thickly wooded glens running nearly to the summits, appear to descend with great abruptness and at once impress one with the boldness of the work. Further, as the Hooleekullbettah (Tiger Mountain) rises directly in front and appears to close completely the valley to the west, it would seem at first that there was no outlet to the basin.

The thin line of ghaut road which is seen climbing along the great mountain spurs to the right, and gradually descending towards the Hooleekullbettah, shows, however, that there is an exit in that direction, and after traversing the road for eight and a half miles (the total length of the Mysore portion) from the head, the spectator finds himself directly fronting this lofty pyramidal mountain, with a wide valley opening seawards on his right hand, and affording an almost endless prospect of the Canara country at his feet.

The Mysore portion of ghaut, which is generally twelve to fifteen feet wide, falls very gently to a point about five and a half miles from Kotegar. Here the line ascends for half a mile, it having been considered inadvisable to attempt to carry it with the same gradient across a rocky cliff nearly 500 feet in height, which here bars the path. As I forward a sketch of this point, shewing the road passing over the top of the shoulder, it will be at once seen how this formidable obstacle rules the gradient of the ghaut so far, and that there existed good reason for the adoption of the present line.

The remaining two and a half miles of road from this point (known as the top of the counterslope) descends with an easy gradient to the Madras frontier, where there is a short zig-zag joining the two traces. Some very formidable obstacles had to be encountered in this portion, the chief of which was the Codakull, (Umbrella Rock,) which formed part of a precipice of sheet rock some 350 or 400 feet in depth, and for a long time effectually baffled all efforts to cross. A happily lodged charge of powder, however, produced a slight displacement, and the whole obtruding mass some 100 feet long by fifteen feet thick becoming detached, rushed into the valley below, and allowed of a sufficiently wide road being established across the ledge. It is unnecessary to dwell upon other impediments of a similar nature as all real difficulty has now vanished, and the completion of the work is only a question of time.

The Madras portion of the ghaut commences near the head of the second valley, which it reaches by being carried along a saddle connecting the first with the Hooleekullbettah, along the northern slopes of which the road is taken, and descends by a series of zig-zags to the foot at the village of Charmondy. Though steeper than the Mysore portion it is wider, and therefore more advanced for cart traffic, but as some rivers in the low country still require to be bridged, the opening of the through line to the coast cannot be looked for immediately. With vigorous efforts I have no doubt that produce could be sent down the ghaut by carts in two years.

Even now in the unfinished state of the road, the amount of traffic carried on during the dry season is very considerable. (In the monsoon, the difficulties occasioned by the great rainfall on this portion of the ghauts, coupled with the dread of meeting wild elephants, which are frequently to be met with in herds at this season, stop all communication). Some days, I am given to understand, the number of pack cattle may be counted by thousands, and there can be no doubt, when complete, the road will become the most frequented on the Western Ghauts, the gradients being easier than on any other, and the communication with the port of Mangalore more direct. This result, too, will appear the more satisfactory if it be borne in mind that the inhabitants of this part of the country were never thoroughly subjugated by any native ruler, and that it is only quite of late years they have ceased to form an *imperium in imperio.*

Of the approaches to the Boond ghaut a few words will suffice. The road leading from Munzerabad to Moodgherry, twenty-one miles in length, passes many valuable coffee estates. At present it is but an unbridged fair-weather road, and will therefore need improvement.

From Kotegar to Moodgherry, and thence to Wustara, Chickmuggloor, Santawarra, and the Bababooden hills, the road is an indifferently bridged line with at one point an almost impracticable ghaut (the Bussawan Cunawai) which must be retraced. A special estimate for raising the whole of this, the main feeder to the Boond ghaut, to the standard of a third class road is now under preparation, and should appear in the next budget.

An estimate for rupees 32,941 stands in the current year's (1863-64) budget, for constructing a road from Chickmuggloor to Cudnoor *viâ* Sacrapatam, and a further amount will be entered next year for making a new ghaut to lead from Santawarra to Lingadhully. These, with other matters connected with the communications in this portion of the country, were dwelt upon in my detailed report, but as they are not of any special interest they need not be further adverted to here.

As my inspection of the Huggary valley, and the site for the proposed Mauri Cunawai tank near Herioor, forms the subject of a special report and estimate now being submitted to Government, I shall not advert to the matter at present; the state of the communications in this part of the province may, however, be remarked on concisely.

The wide area between the Cuddoor, Shemoogah, and Herioor Chittledroog roads, is as yet untraversed by a single road from east to west. Although much of this part of the country, especially the valley of the Huggary, is extremely barren, yet such is not the case throughout. About Chennagherry and other parts there is abundance of black cotton soil, which, from the efforts now being made, will probably prove an abundant source of wealth; there is, therefore, no reason why this part of the province should be left destitute of roads, the more so as it forms a distinct obstacle to communication between the east and western portions of the lately constituted Nuggur division. The Chittledroog district is now practically cut off from Shemogah, which is the divisional head-quarter.

To remedy this, a road is now under execution from Chittledroog to Doomee and thence to Benkipoor, where there is a fine bridge over the Budra. This road should be formed and bridged within two and a half or three years. A short line is also well advanced between Terrikerray and Adjumpore, and I satisfied myself that this could be pushed on through Hossdroog to Herioor at very little cost, the soil being very favorable and the drainage trifling. A plough tax road is also proposed from Hoolyaur though Hoosdroog, Holalkaira to Anagode, on the Chittledroog Hurryhur road. When these shall have been carried out, the country may be considered as fairly opened.

The next point of importance refers to the supply of labor for our works along the ghauts and especially in the Nuggur district. The natives of this part of the country are so independent, (though it will scarcely be credited, several coolies who carried my baggage refused all remuneration, and this I understand is no uncommon occurrence) that the planters as well as our department have to look exclusively to the Lumbanees, who as a class are as much noted for their laziness as their filth.

Natives from other parts of Mysore soon sicken in the Mulnaad (the local name for the country lying under the ghauts to the east), the climate of which they dread. One company of Kalihauts (Mysore Labor Corps) which was sent for work on the Angoombee road soon deserted in a body, and on presenting themselves at Bangalore scarcely a man was able to stand from the effects of fever. The only place from which labor could be drawn to any extent was Canara, but now since the large works at Shedasegur, &c., have been started, this source has completely failed; not a man is to be procured.

One most fruitful source of difficulty with reference to labor, is the competition arising from the extension of coffee plantations. It frequently occurs that no sooner has one of our subordinates by great labor collected a sufficient body of coolies, than a planter's agent steps in and carries off the whole under heavy advances. So common is this occurrence that it is believed to be systematic. An advance in ready money has thus been made to a single influential cooly of 60 rupees the rest of the gang getting smaller sums. While, however, it may be satisfactory to know that some of the planters have politely acknowledged the services the subordinates thus render, the difficulties with which our department are left to struggle are most disheartening.

In justice to the planters it must be admitted that they are at times put to grievous stress for want of labor, and when this occurs at a critical time for the crop they have no choice but to get labor at any price. In Munzerabad only a very few years ago, coolies could be got for Rs. 2-8. They are now 5 and 6 rupees, and ere long will probably be 7 rupees per mensem. In Nuggur the rate has not gone as yet much higher than 4 rupees, but it is rapidly rising.

In the concluding portion of Lieutenant-Colonel Kennedy's Report on the works in north Canara, he draws attention to the grave difficulties attending the supply of labor in that part of the country; when, therefore, I mention that to north Canara, Captain Palmer had till lately to look for much of his labor for the works in the Mulnaad, and that even that source is now cut off, the importance of the question as concerns this department will be sufficiently apparent. Spite of every effort works only creep into existence in Nuggur. No contractors can be obtained. Every subordinate either loses his health there and has to be sent away, or, still worse, deserts his post. This is but plain matter of fact, which I think it right to state in justice to the Executive Engineer.

Yet it is absolutely necessary that the valuable coffee land at the back of the Bababoodens and about Coppa, Kig, Namur, &c., should be opened up, and a line of communication established between the Boond ghaut and the country lying north, much of which has probably never been visited by any European; means must therefore be found for grappling with this labor difficulty.

As in some measure likely to effect this object, I would venture to propose that the great bulk of the Kalihaut Corps, now about 852 strong, be sent to the Boond ghaut and Nuggur; that an apothecary with all requisite medicines be attached to each company, and that every man be given good warm clothing; further, that the pay while so engaged be raised to 6 rupees per mensem. In addition to this I would raise more companies in Nuggur itself, and enlist men if possible down the coast. I do not say that this will succeed; much, however, I think can be done by selecting in the first place really able-bodied men, taking care of them and giving high pay.

The Commissioner has lately seen fit to recommend the advisability of making the Executive ranges conterminous with the new civil districts, and there can be no doubt that if this be acceded to, great relief will be given to the Executive Engineer of Nuggur, who is no less overburthened by the difficulties connected with his subordinates, and the supply of labor, than he is by the undue extent of his range. I now beg to pass on to my tour undertaken during the last week of April, the extent of which is given above, and having already made this report too long, I shall endeavor to be as brief as possible.

One main object of this tour was the inspection of the Railway feeders to the east of Bangalore, which have been under execution during the past year. I found them extremely well laid out, and all, with the exception of the line between Colar and the Marmootal (near Coppum) station, nearly completed. Even on this line rapid progress was being made. There being in no case large streams to cross, the masonry works have been extremely light; still I think the rapid and efficient manner in which they have been executed, shews the great advantage of a proper system of contract by which they have all been carried out. The whole of these roads should be complete by the end of next month, or several months before it is probable the railway will be open to the public.

Proceeding round by Tulgarah and Thadgole, I inspected the fourteen terminal miles of the new Cuddapah road, the frontier being about two and a half miles beyond Ralpand. Much of the end portion of this road lies through a hilly country covered with scrub jungle, and though there is no bridge here above thirty feet span, a good deal of minor lateral drainage had to be provided for. The work has been performed very creditably, and, with the exception of one or two breaks at nullahs in the Madras territory, the line is complete from Bangalore to Cuddapah; and notwithstanding that perhaps no very great amount of through traffic can be expected, it will be a most useful line. New bungalows at Tulgarah and Ralpand had been opened for the use of travellers shortly before my visit.

Returning along the same road I was enabled to examine the trace of the proposed line, thirty-two miles in length, leading from Chintomonipett to Bangapillay *viâ* Sandly, and which it is very desirable should be opened soon, both in the interest of the Railway Company and that of the country generally. I was enabled to suggest several improvements in the trace, which, with other matters, have been dwelt upon in my detailed report. Here it will suffice to say that throughout the line both the soil and gradients are favourable, and setting aside the provision for minor drainage, only three bridges will be required, one over the Pennakerray (three arches of twenty-five feet each), another over the Coosbavutty (one arch of twenty-five or thirty feet), and the third across the Chittravutty river, near Bagapilly, at the junction of the new road with the existing main road from Bangalore to Ghooty. This last river will need seven or eight arches of twenty-five feet.

Some wild rocky country is passed through on this road, and a little blasting will be required. The survey and estimate originally prepared under orders of the Executive Engineer, Mr. Dobbs, will require but little alteration, and will ere long be forwarded to Government for entry in the next budget.

An alternative site had been proposed for crossing the Chittravutty river, but I was led to recommend the one above alluded to as possessing the advantage of placing the Cusbah town of Bagapilly in immediate communication with the main road, and of enabling a plough tax road to be pushed forward, when funds may admit, to the important town of Goomnaickenpollium, which, buried in the rocky mountains to the east, has at present no proper communication with any of the main lines of the country.

On referring to the Trigonometrical Survey it will be observed that the Cusbah town of Goreebednore (about twenty-five miles north-west of

Nundeedroog) is situated in a valley bounded by a range of hills on the east, stretching northwards from Nundeedroog, on the west by the range containing Daveroy and Mudgherrydroogs, and on the south by Munclyproog, and is thus cut off from communication with other parts of Mysore. There exists, it is true, a track through the mountains on the east by which pack cattle and even half laden carts can proceed to Goodybundah and thence to the Bangalore Ghooty road, and again on the south there is a steep ghaut on the south-east of Manclydroog, which gives an exit to some of the produce southwards; but for all the practical purposes of trade the valley is at present excluded from the system of roads in Mysore. The natives consider it as belonging to the country below the ghauts.

For many reasons it is most desirable to alter this state of matters. Not alone is the valley rich and productive, but the Madras (Bellary) authorities are most anxious to have Goreebednore placed in immediate communication with the town of Hindoopoor to the north, to which place they have carried a line in continuation of that leading through Handyanantipoor and Pennacondah.

An inspection of the Map will shew that if we carry a road from Dodabattapoor through Goreebednore to Hindoopoor, we shall not only open up this hitherto closed valley, but lay the basis for establishing a more direct route than now exists from Bangalore to Ghooty and thence to Hyderabad. I inspected the greater portion of this line with Mr. Dobbs, and as a trace will be made before long followed by a detailed estimate, the subject will probably be definitely brought before Government in connection with the next budget.

Another obvious line of road is that which would connect Mudgherry with Goreebednore, and thence through Wottabahosshully and Goodybundah to the main Bangalore Ghooty road. We have now a line almost finished between Seerah and Mudgherry to the westward, and this proposed road would simply form its continuation, piercing the Goreebednore valley from east to west, which is very much needed. The whole of this line, with the exception of the ghaut leading down from Goodybundah to Wottadahosshully, might be constructed from the plough tax fund, the ghaut which will require careful tracing and working out being left to this department for execution.

I may mention that in addition to these lines a plough tax road is projected from Goreebednore to Mauchanhully to the south-east and thence to Chickballapore. The only difficulty in this communication will be a small ghaut leading through the hills between the two latter places. My examination of this ghaut led me to conclude that it must also be carried out by our department, and that before commencing, the line must be accurately surveyed and traced, the ground being extremely difficult and encumbered from end to end by piles of rock.

Before leaving this interesting valley I must make a brief allusion to the Wottadahosshully tank, which is, without exception, the finest work of the kind I have seen in the country. It is situated at the end of the valley which has its head near Goodybundah, and receives the whole of its drainage, converting the country below, opening to the westward into a wide irrigated plain. The approach to the head of this beautiful sheet of water is by the pass in the mountains leading down from Goodybundah; its length, when this tank is full, is perhaps two and a half miles by over half a mile in width. Though thus much smaller than many of the tanks in Mysore, it is remarkable for the great height, (sixty feet) of the bund, which is 12 or 1300 feet long, and most picturesquely situated between the two flanking hills at the end of the valley. The mountains on all sides are composed of heaped-up masses of granite, and the hill to the south against which the bund abuts on that side, cannot be less than 1,500 feet high.

The bund has a solid stone facing on both its front and rear slopes, and differs very much from all other I have seen, not alone in its height, but the manner in which the work has been executed, being quite straight and workmanlike throughout. The immediate object of my inspection was with reference to the sluice, which was reported out of order and for which an estimate had been framed. This I, however, found to be erroneous, and but a trifling amount of work required.

I may now conclude this report by mentioning that the only matter of much importance which further required my attention was the so-called Nundidroog ghaut, situated north of the hill, and on the provincial road leading through Chickballapoor to Colar. It has hitherto been so steep as to prove an effectual bar to through traffic. Though a good sum of money will be required to correct its defects, I was enabled to select a line, which on being worked out will give sufficiently easy gradients.

R. H. Sankey.

No. XVI.

AGRA FORT.

Report of a Special Committee, assembled by order of HIS EXCELLENCY THE COMMANDER-IN-CHIEF, *to consider the question of the improvement of Agra Fort.*

PRESIDENT.

Brigadier St. G. D. SHOWERS, C.B.

MEMBERS.

Colonel F. TURNER, C.B., Bengal Artillery, Agent for Gun Carriages.
Lieut.-Colonel A. CUNNINGHAM, Bengal Engineers, Chief Engineer, N. W. P.
Major J. H. MAXWELL, Bengal Engineers.
Capt. J. D. CAMPBELL, Bengal Engineers, Superintending Engineer, N. W. P.

Agra, 26th January, 1860.

The Committee proceed to take into their consideration, the following subjects, as appear to them indicated in the instructions, namely :—

1st.—Strengthening the fortification as it at present stands.

2nd.—Formation of outworks as affecting the Jumma Musjid and Tripolya, and the construction of detached posts.

3rd.—The levelling and clearing of the ground immediately under the walls of the Fort.

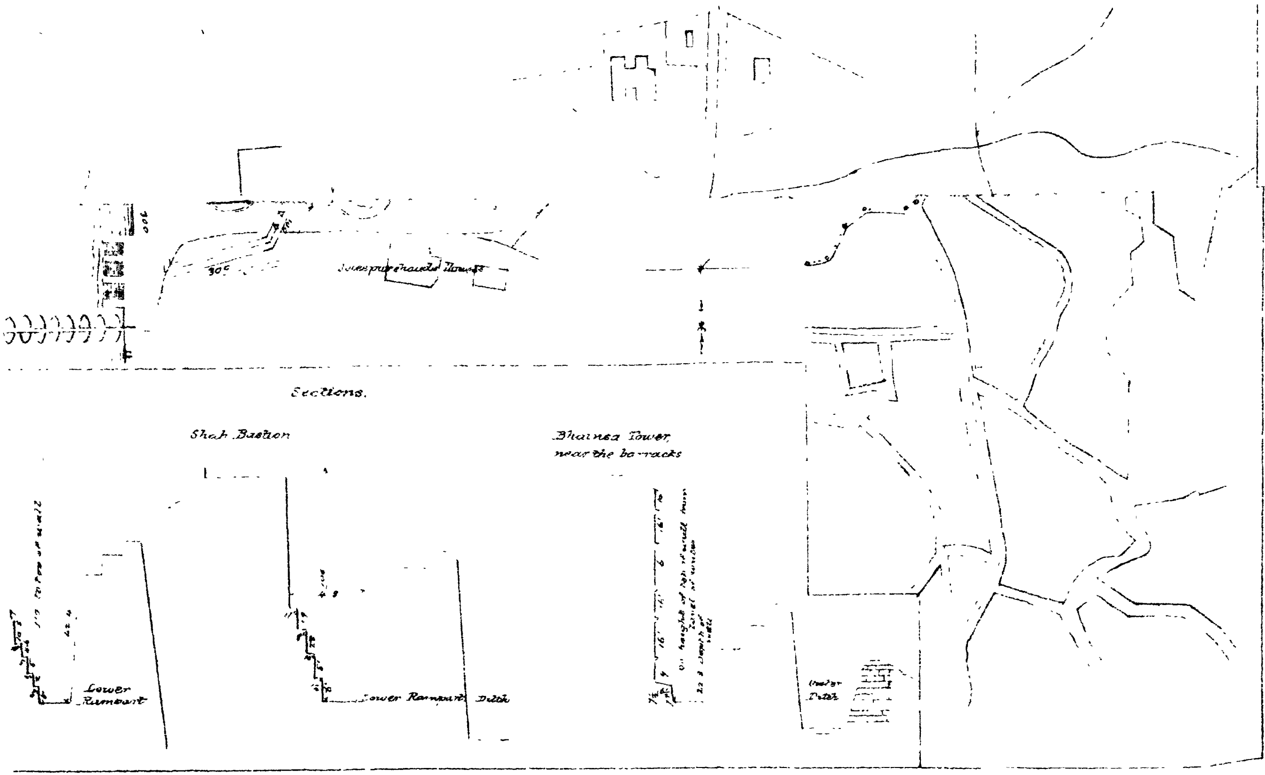
The Committee having discussed these several subjects with plans before them, and having inspected the ground and position, proceed to report as follows.

The chief defects of the Fort of Agra are the following :—

I.—The deficiency of flanking defences.

II.—The want of a glacis to cover the scarp walls.

PLATE XXI.


Jorespurchauki Tower
300
30°
Sections.
Shah Bastion
Bhainsa Tower,
near the barracks
Lower
Rampart
Lower Rampart Ditch
Outer
Ditch
16'
6
16'
9
height of top of wall from
level of [illegible]
depth of
wall
17
42

III.—The great height of all the batteries above the country, and the consequent plunging and defective nature of the fire, which is ineffectual at short ranges.

IV.—The inequality of the ground on all sides, and the dangerous vicinity of the city on the north and west faces, affording cover to an enemy, to within breaching distance of the walls.

The Committee beg to offer the following suggestions, with a view to lessen, or entirely remove, the serious defects above noted.

I. As to *the deficiency of flanking defences*, we are of opinion that these may be effectually improved by the construction of works in connection with the fort itself, namely,

First.—Earthen bastions outside the corner towers on the river face.

These bastions should be completely isolated from the *fausse braie* by ditches, and be connected with the body of the place by gates. One of these gates, (for the bastion at the north-east corner,) already exists in the northern curtain close to the Shah Boorj tower; and another (for the south-east bastion) exists on the river face of the out-work of the Ummur Singee gate.

These bastions will be so disposed as to afford flanking fire not only to the river face, but also to the north and south fronts, respectively. They will also cover the two weakest points of the fort, which a besieger would be sure to select for attack (and one of which, the south-east tower, was that of Lord Lake's attack). Further, in conjunction with the Water-gate bastion in the centre of the river face, (which will subsequently be noticed in detail,) they will cover with their fire all the ground on the opposite side of the river, which an enemy, contemplating attack on that side could occupy with his batteries, as it is within range from 600 to 1,200 yards.

The proposed north-east bastion also completely covers all approaches to the bridge on both sides of the river, and assists in the flanking defence of the works which are proposed for the Jumma Musjid, within a range of 700 yards.

The new bastion on the south-east provides defence on the line of approach from the direction of the Taj. It also sweeps with its fire, within easy range the two principal ravines on the south side, and covers the approach to the Ummur Singee gateway.

Second.—The conversion of the Water-gate and contiguous bastion (which at present form part of the lower fort on the river side) into a Horn work, cut off from the lower fort, and connected with the body of the place. This work will cover the Water-gate, and complete the flanking defences of the river face. It will also afford direct fire on the opposite side of the river; it will cover the approach to the bridge from the other side, and co-operate with the flank bastions in the general defence of that front.

The Committee are of opinion that the new works, above described in general terms, will suffice for the protection of that part of the fort.

Third.—For the flanking defences on the land side, the following works seem fully sufficient.

On the north covering tower, No. 9, should be constructed a Counterguard with flanks, for the purpose of affording flanking fire right and left on the northern face. Any more salient work would be objectionable, as advancing the defences towards the city, already too near. The communication with this will be from the *fausse braie* by a bridge across the ditch.

At the north-west corner are the Chowk, the Tripolya and the Jumma Musjid, covering the approach to the Delhi gate. These buildings must either be removed or occupied. If removed, a work of some description to afford flanking fire must be erected on their site. The Committee, however, think it would be more advantageous to occupy them, by forming them into a permanent outwork, which may be thus effected.

The Tripolya, (a small walled enclosure connecting the Chowk with the Jumma Musjid,) with one side of the Chowk, and a portion of the rear wall of the court of the Musjid, must be removed, so as to throw open the interior of the Musjid to the fire of the place. The side walls of the Chowk must be prolonged to connect it with the Musjid. The standing portion of the rear wall of the court of the Musjid can then be formed into a 2-gun battery, which will flank the proposed counterguard and new bastion on the north. The Musjid itself is also capable of being turned into a very formidable battery. Five embrasures may be pierced through its western wall, which is 11 feet thick, and very solidly built, and two in each side wall of the mosque itself. The side walls of the court-yard will also afford positions for several guns, which on the south side will most effectually sweep the main road to the Delhi gate, as well as much of the low broken ground to the south-west of the Fort. The battery on the west will command a large ravine which would otherwise afford excellent cover for an enemy's approach.

As the piercing of the embrasures through the western wall must be a work of time and labor, it should be begun at once. The embrasures themselves may then be closed by thin screen walls, and the building itself thrown open for the use of the Mahommedan population, as convenient access can be had by the two gateways in the side walls. These gateways would be closed by sandbags, or other effectual means, on any emergency; and if desired, they can always be closed by the strong iron covered doors at present in them.

The Chowk likewise should be made part of the position, by covering its wall with a glacis, leaving the existing road to form the bottom of the ditch, which must also be carried round the Musjid.

It is necessary, however, to note that the houses of the city actually touch the north west corner of the Musjid, and are quite close to the building on other sides, so that to admit of this being retained as an outpost it becomes absolutely requisite to remove a portion of these suburbs, at least to the extent of 200 yards. A greater open space, if it could possibly be obtained, would, in the opinion of the Committee, be most desirable, and in accordance with military principles.

To obtain flanking fire on the south-west front of the Fort advantage should be taken of the high ground immediately to the west of the Ummur Singee gate, on which to throw up a strong ravelin with flanks, of a permanent character, to be connected with the place by a *caponiere* and covered passage leading into the main ditch.

The faces of this work will be swept by the guns of the body of the place, and they will themselves command by their fire the broken ground to the west and south of the Fort. Its flanks will cross fire with the batteries of the Jumma Musjid and the new bastion on the south-east.

Between the high ground on which it is proposed to make this ravelin and the Fort, runs one of the principal lines of drainage of the city and cantonments, which should be converted into an outer ditch, to be enfiladed by the flanks of the ravelin, which will be rendered more secure by throwing stockades across, on the prolongation of the flanks.

II. With regard to the second defect; *the exposed state of the scarp wall of the ditch, and general defectiveness of the glacis, and in many parts the total want of one,* it should be stated that at present the counterscarp wall is generally at least five feet too low for the efficient protection of the scarp wall of the ditch, and the earthwork of the glacis is not even carried up to the top of the existing wall, so that one-third, and in places, one-half of the wall being visible, a practicable breach might readily be formed by the enemy's batteries from a distance. To obviate this important defect the Committee strongly recommend, that the counterscarp wall should be raised and the glacis properly formed and completed.

III. With reference to the third point; *the defective nature of the fire from the body of the place, owing to the great height of the wall,* the Committee beg to recal the recommendation of the Committee of Engineer Officers, assembled in 1857, that the walls should be lowered; and to suggest instead, that embrasures should be opened in the curtain walls, on the ground level of the Fort, wherever available; and that the only guns on the high towers be of large calibre, on pivot or traversing platforms, and confined to the most salient towers. These pivoted guns on the towers will assist the flanking fire afforded by the proposed new works; and the demi-casemated batteries of the curtains will, at a much more favorable level, (about 25 feet below the present towers,) protect and cover the ground in their fronts by direct fire. The great height of the walls, the Committee consider a decided advantage, as it precludes the possibility of escalade; and even when breached, the height will still offer a formidable obstacle, almost an insurmountable one, if the ground behind the breach be properly retrenched.

IV. The Committee desire to remark on *the broken nature of the ground around the Fort,* and on the immediate neighbourhood of buildings, which would afford perfect cover to large bodies of hostile troops in close proximity to the walls, and thus give them the means of establishing their breaching batteries unseen.

On the northern side, the broken ground consists of the *debris* of that part of the city which was thrown down during the outbreak. The Committee recommend that the *debris* on this side should be formed into a second or outer glacis. As this is the weakest side of the fort, on account of the cover afforded by the houses of the city, this advanced glacis will be of considerable advantage, as it will more effectually screen the main wall, and so prevent a besieger from establishing his batteries under shelter of the city houses, and force him to advance to the crest of the glacis by the usual process.

On this side there are immediately under the walls two houses left standing, which it will be necessary to remove; also a wall several feet high defining the limit of the fort lands on the city side. The rubbish may be thrown into a sunken road close by, which will thus be brought up to the general level.

On the south-west side leading down from Boileaugunge to the Delhi gate, there is a sunken road which can only be seen to any extent from the Jumma Musjid. The steep side of this road towards the Fort should be sloped off so as to expose the whole line to the view of the place.

On the south side, the broken ground is far more intricate and extensive. Here also the same general principle should be followed of sloping off the mounds from the fort outwards, so as to present a succession of glacis, and expose their whole extent as much as possible to the view of the fort.

With regard to the most prominent of these mounds, it may be necessary to occupy some of them by light field works, so as to command as far as possible the uneven ground in their front. These works should consist merely of a light parapet and ditch open to the rear; but their exact forms and positions can only be determined when the permanent improvements of the fort are decided upon. As the new defences are to be chiefly earthworks, and as very extensive levelling will also be required, it appears to the Committee that it might be more cheaply and expeditiously effected with the aid of some companies of the Corps of Sappers and Miners.

In the event of the removal of the Arsenal from Delhi to Agra, and with reference to the increased armament rendered necessary by the enlargement of the works, it appears to the Committee that provision should be made for more extensive magazines for powder. They therefore take leave to suggest the open square in the middle of the Meena Bazar as the safest and most centrical position for that purpose. The place proposed is 114 feet square, already suuk upwards of 20 feet below the level of the surrounding ground, and would afford room for capacious magazines which could only be reached by vertical fire.

The *Armament* of the Fort should, in the opinion of the Committee, be as follows:—

On each of the high towers,* (which if not sufficiently strong, should be made so,) there should be one 8-inch shell gun, on a pivoted or traversing platform, which will command, to a wide circuit, all the broken ground and houses.

From the great height of these towers, it will be easy to afford cover to the artillerymen when working the guns, and the Committee consider that this armament will be ample for these towers, the fire from which from ordinary guns on account of their great height, would be very ineffective.

There should be embrasures pierced through the main walls in as many of the curtains as will admit thereof; and these batteries should be armed with 18 or 24-pounder iron guns, as most available. As the ordnance in these batteries would be partly under cover, and particularly well defiladed, it would be economical to mount them on iron carriages. The Committee anticipate that batteries of the above nature should be made in the curtains† to contain about five guns each, forming a total of 40 guns.

The nature of the ground around the fort, renders vertical fire from mortars very desirable, and the Committee would point out the following sites as good positions for batteries:—

First.—In the south-east angle of the Fort near the Jehangir Muhul, from which shells may be thrown into the broken ground on the south and across the river;—a *second* battery might be placed near the present barracks; and a *third* on the grand parade.

These positions would be taken up, on the necessity occurring, but mortars of the heaviest calibre, for the armament of the place, should be specially retained in the fort.

The Committee would limit the armament of the *fausse braie* to the formation of batteries in the bastions of the outworks in front of the gateways; as in any other parts the *fausse braie* is so narrow, and the main walls so high, that the batteries would be untenable from the splintering of the stones under the enemy's shot.

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* Nos. 1, 2, 4, 6, 7, 10, 11, 18.

† The curtains, one on each side of the Ummur Singee gate, and one on each side of the Delhi gate—also to the right and left of the Futeh Boorj on the north, and the curtain of Ummur Singee outwork, and one on the water face where found practicable.

The ordnance should be as follows:—

At the Ummur Singee gateway, three guns and one howitzer, in each bastion.

At the Delhi gateway, a similar armament.

The armament of the new works outside the Fort, should be as follows:—

For the two new bastions on the river face:—

IN EACH BASTION,	1	8-inch howitzer, 24-pounder gun,	per flank.
	1		
	1	8-inch howitzer, 24-pounder guns,	per face.
	2		

For the Counterguard north front, two 24-pounders in the east flank, to sweep the face of the proposed new bastion. One howitzer, 8-inch, and one gun in west flank, to cover the Jumma Musjid and city.

For the Jumma Musjid outwork. For the front, three guns to sweep the ravine, leading right upon it and the neighbouring suburbs, and two guns in each of the three remaining sides.

For the Ravelin in the south-west part field guns and howitzers only are deemed necessary. The faces and flanks should be pierced with embrasures for ten or twelve pieces, say two in each flank, and three or four in each face.

ABSTRACT OF ARMAMENT.

Body of the place.	8-inch shell guns in bastion, ...	8
	Siege iron guns in casemates, ...	40
	13 and 10-inch mortars, ...	12
Fausse braie.	Siege iron guns, 24-pounders, ...	12
	8-inch howitzers, ...	4
River bastion.	24-pounder iron guns, ...	12
	8-inch howitzers, ...	4
Counter-guard.	24-pounder iron guns, ...	3
	8-inch howitzer, ...	1
Jumma Musjid.	24-pounder iron guns, ...	5
	8-inch howitzers, ...	4
	Total Iron Guns, ...	105
Ravelin.	9-pounder brass field guns, ...	8
	24 " " howitzers, ...	4
	Total Brass Guns,... ...	12

with a proportion of field guns, and 5½-inch brass mortars available, as circumstances may demand their use.

From the Secretary to the Government of India, with the Governor General, to the Secretary to Government, N. W. Provinces, P. W. Department.

Benares, 8th December, 1860.

SIR,—The Governor General having had before him the report of a Committee, convened under orders from this department in December last, on the improvement of the defences of the Fort of Agra, with reference to the contemplated removal to that place of the arsenal establishments from Delhi, has come to the conclusion that the great cardinal object of reducing to the smallest dimensions all strong places, the retention of which is a necessity so long as we retain India, has not been sufficiently kept in view by the Committee.

His Excellency is of opinion that the outworks proposed by the Committee, are objectionable as rendering it necessary to maintain a larger garrison, and being in themselves a source of weakness rather than of strength.

The irregular ground outside of the Fort, should, as recommended by the Committee, be sloped off, so as to present a succession of glacis, and expose the whole extent as much as possible to the view and fire of the fort.

A glacis and covered way should be formed; the counterscarp being strengthened by counterforts where necessary, to make it support the additional weight of earth.

The Jumma Musjid should neither be destroyed nor occupied, but mined so as to admit of its being blown up in case of necessity. Embrasures, not concentrated in batteries, but scattered, should be pierced in the walls, so as to give a fire at a lower level than from the top of the walls.

To carry out the above measures, the Military Department has been this day requested to move His Excellency the Commander-in-Chief, to place a company of Sappers under an intelligent officer, at the disposal of the Superintending Engineer, and I am to request that His Honor the Lieutenant Governor, will have the goodness to authorize the Superintending Engineer to allow the officer in question to draw funds to the extent of one thousand rupees per mensem, from the Executive Engineer, for laborers to be employed under the supervision of the Sappers, and for materials and miscellaneous expenses connected with the works. He should of course be required to furnish proper accounts, and to report progress of work.

I am further to request that the Public Works and Civil Officers may be called upon to submit estimates of the cost of removing Jotee Persad's house, situated on the northern side of the fort, and for effecting a clearance round the Jumma Musjid.

A report is likewise required from the Superintending Engineer, as to whether space could be found in the fort, to erect two or more earthen cavaliers, on which the garrison could, in case of need, place batteries which would enable them to return the fire of assailants, after the masonry walls should have been so injured as to be incapable of bearing guns.

A further report by the Superintending Engineer is requested, as to the armament that will be necessary for the fort, with reference to the above contemplated arrangements.

The Committee have selected the Meena Bazar, as the site for the powder magazine. This has the approval of the Governor General, but the estimate for the work may be deferred until the arrangements in regard to the ordnance magazines in the Agra fort, shall have been settled in the Military Department, so as to define the accommodation to be retained for that purpose.

C. H. Dickens.

No. XVII.

MACHINES FOR RAISING WATER.

Calculation of the labor, and cost of raising water by the different machines employed in India by the Natives. BY SERGEANT J. WEBSTER, *Assistant Master, Thomason College.*

THE heights assumed for raising the water in each case are those for which it is believed the several machines could be most generally and usefully employed.

The value of the modulus and the useful effect in each case are assumed after due consideration of the structure of each machine and the amount of spillage or waste.

1. THE BEAM AND BUCKET.

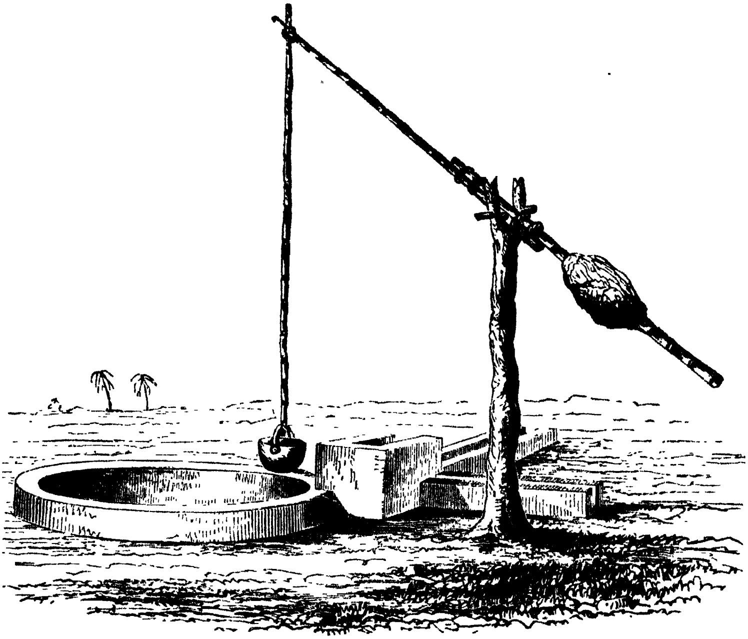
(One man employed.)

Water raised 16 feet.
Content of bucket = ·45 cubic feet = 2·8 gallons.
Average time of raising the bucket = 20 seconds.
Number of discharges per minute = 3.
Discharge per minute = 3 × ·45 = 1·35 cubic feet = 8·4 gallons.
Discharge per hour = 81 cubic feet = 506 gallons.
If we take the useful effect or discharge at 90 per cent, we get—
Actual discharge per hour = 72·9 cubic feet = 455·4 gallons.

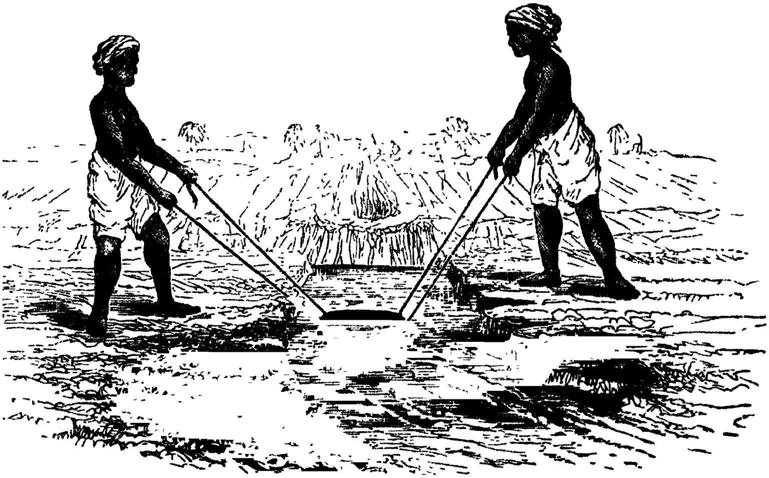
2. BALING.

(Two men employed.)

Water raised 5 feet.
Deliveries in each minute = 20.



THE BEAM AND BUCKET.



BALING.

One delivery = $\frac{1}{3}$ cubic foot = 2·1 gallons.
Delivery per minute = $\frac{20}{3}$ cubic feet = 42 gallons.
Delivery per hour = 400 cubic feet = 2520 gallons.
If useful effect = 75 per cent., then—
Actual discharge per hour = 300 cubic feet =1890 gallons.

3. THE SINGLE MÔT.

(One man and two bullocks employed.)

Water raised 40 feet.
Speed of bullocks = 2 miles an hour.
Space gone over by the bullocks at one lift = 80 feet.
Content of bag = 3 cubic feet = 18·75 gallons.
Weight of water raised at each lift = 187·5 pounds.
Time required for bullocks in turning = ·4 minute.

Speed of bullocks per minute = $\frac{5280 \times 2}{60}$ = 176 feet.

Therefore time required to pass over 80 feet = $\frac{80}{176}$ = ·45 minute; and time required for one lift = ·45 + ·4 = ·85 minute.

Number of lifts per minute = $\frac{1}{\cdot 85}$ = 1·18.
Discharge per minute = 1·18 × 3 = 3·54 cubic feet = 22 gallons.
Discharge per hour = 213·6 cubic feet = 1320 gallons.
Useful effect = 70 per cent.
Actual discharge per hour = 149·5 = 924 gallons.

Taking the modulus = ·9 and the weight of the rope and bag = 42 pounds, the required traction which the bullocks have to overcome is $= \frac{187 \cdot 5 + 42}{\cdot 9} = \frac{229 \cdot 5}{\cdot 9}$ = 255 pounds; and one bullock = 127 pounds.

4. THE DOUBLE MÔT.

(One man and bullock employed.)

Water raised 40 feet.
Speed of bullocks = 2 miles an hour.
Speed of bullocks per minute = 176 feet.
Diameter of barrel = 3 feet.
Diameter of bullock walk = 16 feet.

Length of bullock walk $= 16\,\pi = 50{\cdot}2$.

Number of turns of bullock per minute $= \frac{172}{50{\cdot}2} = 3{\cdot}4$.

Turns required for drawing up the bag $= \frac{40}{3\pi} = 4{\cdot}25$.

Time required for drawing up the bag $= \frac{4{\cdot}25}{3\,4} = 1{\cdot}2$ minute.

Time for disengaging the barrel and lowering the bag $= {\cdot}2$ minute.

Total time for raising the bag $= 1{\cdot}4$ minute.

Content of bag = 3 cubic feet = 18·75 gallons.

Discharge per minute by one bag $= \frac{3}{1{\cdot}4} = 2{\cdot}1$ cub. ft. = 13·4 gallons.

Discharge per minute by 2 bags = 4·2 cubic feet = 26·8 gallons.

Discharge per hour by 2 bags = 252 cubic feet = 1608 gallons.

Useful effect = 65 per cent.

Actual discharge per hour = 165·8 cubic feet = 1045 gallons.

Space moved over by the bag at one revolution $= 3\pi$.

Space moved over by the bullocks at one revolution $= 16\pi$.

Ratio of power and weight = 3 : 16 or 1 : 5·3.

Weight of water contained in two bags = 375 pounds.

Weight of bags and ropes = 85 pounds.

Total weight to be raised = 460 pounds.

Taking the modulus = ·7, we get—

Work applied $= \frac{460}{{\cdot}7} = 657$ pounds.

Required traction $= \frac{657}{5{\cdot}3} = 124$ pounds.

5. THE SINGLE PERSIAN WHEEL.

(One man and two bullocks employed.)

Water raised 40 feet.

Diameter of driving wheel = 4 feet.

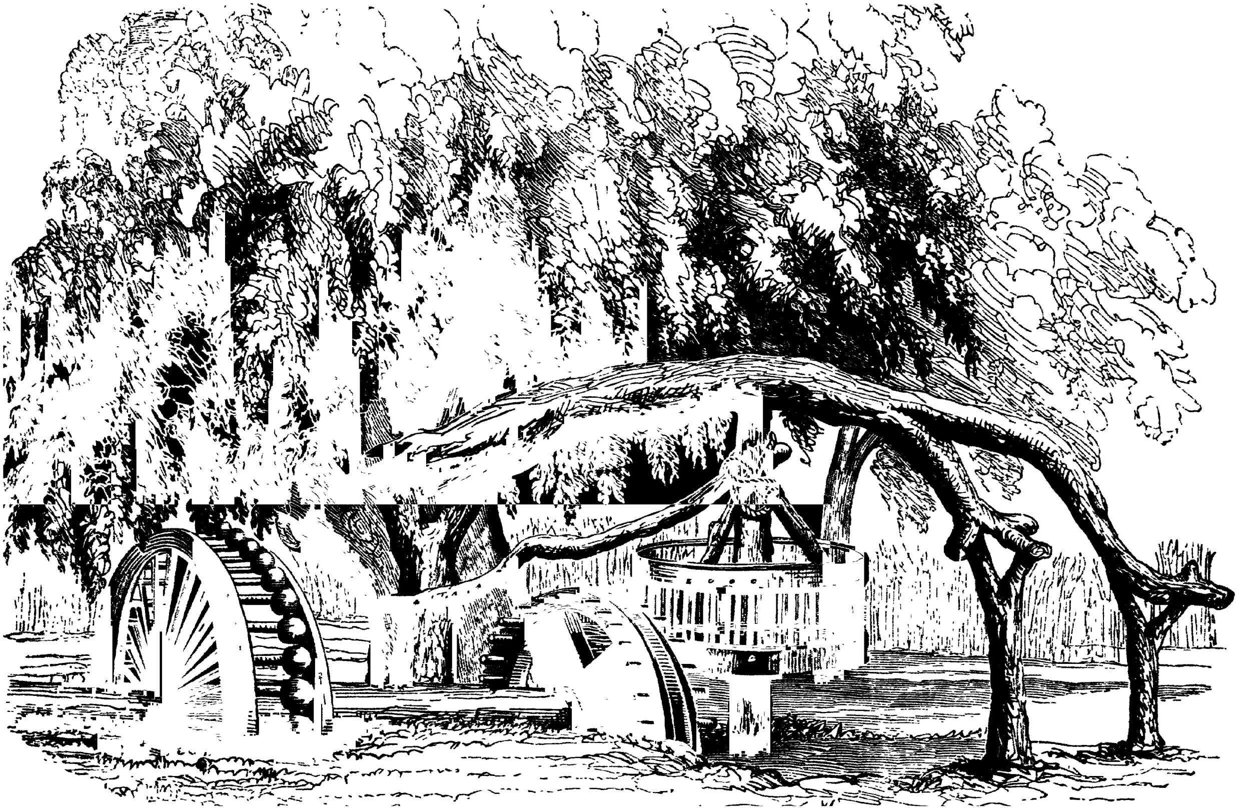
Diameter of bucket wheel = 4 feet.

At each turn of the bullocks, 6 buckets are emptied, and assuming the content of each bucket $= \frac{1}{8}$ cubic foot, we have—

Discharge at each turn $= \frac{6}{8} = \frac{3}{4}$ cubic foot = 4·7 gallons.

Length of bullock walk $= 20\,\pi = 62{\cdot}8$ feet, and speed of bullocks = 2 miles an hour, we get—

Speed of bullocks per minute = 176 feet.



Number of turns per minute = 2·8.
Discharge per minute = 2·8 × $\frac{3}{4}$ = 2·1 cubic foot = 13 gallons.
Discharge per hour = 126 cubic feet = 780 gallons.
Useful effect = 55 per cent.
Actual discharge per hour = 69·3 = 429 gallons.
Buckets are 2 feet apart.
Number of buckets required = 40.
Weight of buckets = 80 pounds.
20 buckets being always full, the weight of the water they contain $= \frac{20 \times 62{\cdot}5}{8}$ = 156 pounds.
Weight of rope = 22 pounds.
Total weight to be raised = 258 pounds.
Space moved over by the buckets at one revolution = 4π.
Space moved over by the bullocks at one revolution = 20π.
Ratio of power and weight = 1 : 5.
Modulus = 0·6.
Work applied $= \frac{258}{{\cdot}6}$ = 430 pounds.
Required traction $= \frac{430}{5}$ = 86 pounds.

TABLE SHOWING THE COMPARATIVE PERFORMANCE AND COST OF THE ABOVE MACHINES IN RAISING WATER TO THE SAME HEIGHT (40 FEET.)

The expense of a laborer is put down at 2 annas and of a bullock at 4 annas per diem. Duration of work per diem = 8 hours.

No.	Methods.	Stages.	Useful effect per cent.	Discharge per hour.		Discharge per diem.		Ratio of discharges.	Employs.		Daily expense	Quantity of water raised for one rupee.		Remarks.
				Cubic feet.	Gallons.	Cubic feet.	Gallons.		Men.	Bullocks.	Annas	Cubic feet.	Gallons.	
1	Beam and bucket, . .	2·5	90	29·07	181·4	232·5	1451·5	1	2	...	4	930	5806	Discharge increased with decrease of height.
2	Baling, ...	8	75	37·5	236·2*	300	1875	1·29	4	...	8	600	3750	Ditto.
3	Single Persian Wheel, .	1	55	69·3	429	554·4	3432	2·4	1	2	10	887	5491	Discharge the same at any height.
4	Single Môt, ...	1	70	149·5	924	1196	7392	5·1	1	2	10	1911·8	11827·2	Discharge increased with decrease of height.
5	Double Môt, ...	1	65	165·8	1045	1326·4	8360	5·7	1	2	10	2096·6	13478·5	Ditto.

The cost and wear of the machines are not taken into consideration.

* Being ⅛th of the quantity raised 5 feet high as computed at p. 173.

J. WEBSTER.

No. XVIII.

SOHAN BRIDGE—LAHORE AND PESHAWUR ROAD.

Designed, and now being constructed by LIEUT.-COLONEL ALEXANDER TAYLOR, C.B., R.E.,

To The Chief Engineer and Secretary to Government Punjab, P. W. D.

Murree, 7th May, 1862.

SIR,—I have the honor to submit a revised design and estimate for a Bridge over the Sohan river. The work proposed is entirely of masonry, and is less expensive than a bridge having masonry piers and timber superstructure with the same width of roadway and same waterway.

The area drained by the Sohan at the site of the bridge is about 573 square miles, and is very compact in shape. The greatest depth of the river in floods is 15 feet, and the mean velocity about 8 or 9 feet per second. The slope of the bed is at the rate of 14 feet per mile. The calculated mean velocity is 13 feet per second. The discharge calculated from cross sections of the stream, is in extreme floods about 91,000 cubic feet per second, which is equivalent to about ¼ of an inch over the entire catchment basin. The bed of the river exposed to view, consists of boulders, water flows all the year round, and is never less than 1 foot in depth. The true bed of the river is no doubt the hard red clay of the country, over that may be expected a layer of blocks of conglomerate, and over that some 12 or more feet of boulders.

In the design proposed, the foundations of the drop walls, and of the piers and abutments are all carried through the boulders and conglomerate blocks,and rest on the hard clay.

At the site selected for the bridge, the river is rather wide, being over 1000 feet, while a few hundred feet higher up, the width does not exceed 750 feet. (*See* accompanying plan.) The clear waterway of the bridge is 945 running feet.

The excavation of the foundations in accordance with the design now submitted is being vigorously proceeded with, and I hope that a good deal of the foundation masonry will have been executed by the beginning of the rains. The excavation is now 11½ feet below water, and the influx of water is under 80 cubic feet per minute, while we have means ready to pump out double that quantity. At 11 feet we have met with the tops of some conglomerate blocks which renders it probable that the depth to the clay bottom assumed at 16 feet will suffice.

The tramway bringing stone from the quarry is in full work.

The Governor General has already expressed his approval in regard to the leading features in this design, that is, the width of roadway and the substitution of masonry for timber. For foundation work, the present and the next months are very valuable, and this coupled with the foregone approval to the change in design, has induced me to push on with the work in anticipation of final sanction.

The cost of a timber bridge without any flooring was estimated at 4,50,000 Rs.

The cost of the masonry bridge with flooring, and in all respects complete is estimated at 4,28,271 Rs.

Early intimation of sanction to this design is requested, that arrangements may be made for the supply of the large number of bricks that will be required.

REPORT.

The original design consisted of 10 spans of 100 feet each. The superstructure was of timber on masonry piers, and the bridge was not floored. The design now submitted consists of 15 spans of 63 feet each, entirely of masonry and the bridge is floored throughout. It is less expensive than the original design with the same waterway, and same width of roadway.

SPECIFICATION.

The foundations to rest throughout on the clay bottom of the river. The masonry below the flooring to be of coursed rubble, the faces not

to be dressed. The floor to consist of large blocks of stone well fitted, and the end stones to be of the largest size and cut to fit closely.

From the floor to the spring of the arches the masonry to be of the best coursed rubble in large blocks with dressed faces. The imposts to be accurately cut.

The arches, spandrel walls, and superstructure of parapets to be of best brick-work. The cornice to be of cut stone. The surface drainage of roadway to be discharged through the crown of each arch, by an iron pipe just clear of the wheelguard.

The entire surface of the roadway to be metalled with broken stone.

The stone to be used is sandstone, from the quarry on the Leh Nullah, and none but the very best quality of stone is to be put into the work.

ABSTRACT OF ESTIMATE.

		R.	A.	P.
1,56,694	Cubic feet cut brickwork, at Rs. 35 per 100, - - -	54,842	9	0
21,924	„ cut stone masonry, at Rs. 50 per 100, - -	10,962	0	0
3,04,271	„ rubble masonry in superstructure with dressed faces, large blocks, at Rs. 25 per 100, - - - - -	76,067	7	0
3,24,844	Cubic feet rubble masonry in foundations, at Rs. 22 per 100,	71,465	7	0
22,03,500	„ excavation for foundations in boulders and water, at Rs. 20 per 100, - - - - - - - -	44,070	0	0
61,00,000	Cubic feet excavation in drainage cuts, partly dry and partly in water, at Rs. 9 per 100, - - - - -	54,900	0	0
15,522	Cubic feet boulders for metalling, at Rs. 2 per 100, -	310	4	0
15,522	„ „ to be broken, at Rs. 3 per 100, - -	465	7	0
15,522	„ „ „ consolidated, at Rs. 1 per 100,	155	2	0
15	Centerings, at Rs. 1,600 each, - - - - - -	24,000	0	0
	Pumping and pumping machinery, - - - - -	60,000	0	0
29	Iron drainage pipes, 4 inches thick, at Rs. 22 each, - -	638	0	0
	Probable loss on ironwork prepared in furtherance of original design being one-third of cost., - - - - -	10,000	2	0
	Total, - - - -	4,07,877	6	0
	Contingencies at Rs. 5 per cent.,	20,393	8	0
	Grand Total, - - -	4,28,271	0	0

A. TAYLOR, LIEUT.-COLONEL,
Superintendent, Lahore and Peshawur Road.

No. XIX.

REPORT OF THE OPERATIONS OF THE GREAT TRIGONOMETRICAL SURVEY OF INDIA, DURING 1862-63.

By MAJOR J. T. WALKER, R.E., *Superintendent G. T. Survey.*

To the SECRETARY TO THE GOVERNMENT OF INDIA, *Military Department.*

Dehra Doon, 1st September, 1863.

SIR,—I have the honor to report the progress of the Trigonometrical Survey during the past official year.

In accordance with the sanction of Government, I proceeded, in the autumn of 1862, to Vizagapatam to measure a Base line. Vizagapatam is situated nearly on the same parallel of latitude as Bombay; and is the point where the Bombay longitudinal series, when extended eastwards to the Madras coast, will terminate. This series of triangles will form, with the Great Arc Meridional, the Calcutta Longitudinal, and the coast series, a vast quadrilateral figure, circumscribing the meridional series of triangles which are required as a basis for the interior topographical details. Base lines had been measured several years ago, by Colonel Everest, at Beder, Seronj, and Calcutta, the S.W., N.W., and N.E. angles of this quadrilateral. One more Base line remained to be measured, which, for considerations of symmetry it was desirable to place in the vicinity of Vizagapatam.

Captain Basevi, the officer in charge of the coast series, being located at Vizagapatam, was directed to select the site. After several trials, owing to the difficulty of carrying a straight line, several miles in length, so as to avoid the numerous irrigation tanks with which this district is studded, he eventually succeeded in finding a suitable line on the undulating plain between the military stations of Vizagapatam and Vizianagram, at a distance of about fifteen miles to the west of the port of Bimlipatam. The ground was chosen before the commencement of the rainy season of 1862, when trenches were dug to carry away the expected rain-fall during the monsoon, and every precaution was taken to keep the line dry. But when Captain Basevi took the field early in October, he found that the rains had been so heavy, that the surrounding tanks had been converted into lakes, and the line lay submerged under a sheet of water, in some parts as much as sixteen feet deep. By great exertions the water was drained off into adjoining ravines. A portion of the line was ready for measuring, on my arrival in December, and the remainder had become fairly dried by the time it was reached, in the course of measurement.

The apparatus employed, consisted of a set of compensating bars and microscopes, on the principle of those designed by Colonel Colby, for the Ordnance Survey of Great Britain, which had been constructed under the superintendence of Colonel Everest, by whom they were brought out to India in 1832. This apparatus has been employed in measuring three Base lines on the great arc, two at the north and south extremities of the Calcutta meridional series, and two at the extremities of the Indus series. The length of these bases has, in each instance, been determined in terms of ten foot standard bar A the unit of measure of the Indian survey.

At the time this standard was constructed, it was believed that the length of a well made iron bar, supported by rollers at its points of least flexure, might be considered invariable for any given temperature. But, of recent years, there has been a growing tendency to doubt the invariability which has hitherto been assumed. Series of comparisons made by the Ordnance survey show there is much probability that the texture of an iron bar changes gradually in the course of years ; for the factors of expansion obtained from groups of comparisons made at intervals a few years apart, differ from each other by larger quantities than are due to errors of observation. It is preferable, therefore, to employ several standards, constructed of different metals, than to trust to the integrity of a single bar.

To ascertain whether our standard has altered in length, it would be necessary to re-measure the whole, or part, of one of the Base lines which were first measured after the arrival of the bar from England. I wished to obtain some light on this subject, by re-measuring certain short sections of the Calcutta Base line, the extremities of which were originally indicated by permanent marks. But, on examining the positions of the section mark-stones, I found that, though concealed from view, there had been a regular thoroughfare over them, for many years, of carts and elephants, as well as foot passengers; consequently, they must, in all probability, have been disturbed, and they cannot be safely referred to, to decide so delicate a matter as the constancy of the standard.

Disappointed at being baffled in my efforts to investigate this matter, by any simpler and shorter process than the re-measurement of a whole Base line, I determined to mark the intermediate section stations of the Vizagapatam Base as permanently as the extremities, in order that any future enquiry regarding the length of the standard, at the time of the measurement of this Base line, may be conducted without greater labor than the re-measurement of a short section.

It has been well said, by one of the greatest living authorities on scientific matters, that "the ends of a Base line should be guarded with religious veneration." In this country they are liable to be viewed with mingled cupidity and dread; the natives sometimes fancy that money is buried below, or they superstitiously fear that the Englishman's mark will cast a spell over the surrounding district. In either case, the mark is liable to be destroyed, as has already happened at the Seronj Base line.* To ensure the protection of the ends of the Vizagapatam Base, I have had substantial domes of cut stone masonry built over them, without any openings, so that, before the marks can be reached, the domes must be pulled down, which will be so laborious, that the police should be able to hear of and arrest the perpetrators, before they have had time to harm the marks.

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* On this subject, the following extract is taken from a letter by Colonel Sir George Everest, C B., to the President and Council of the Royal Society, dated 8th April, 1861:—

"The natives of India have a habit, peculiar to human beings in that state of society, of attributing supernatural and miraculous powers to our instruments, and the sites which have been occupied by them. In cases of death, or any other natural visitations, they often offer up prayers to those sites, and if the object of their prayers be not conceded, they proceed to all sorts of acts of destruction and indignity towards them: nay, as in all cases where it was practicable, my station marks were engraved on the rock, *in situ*, they have been known to proceed in bodies, armed with heavy sledge hammers and beat out every vestige of the engraving."

Captain Basevi and the Assistants of the Coast series party, shared in the measurement of the Base line, which occupied about two months. The length of the line is six and a half miles. It was divided into three verificatory sections, which were subsequently checked by two series of triangles, one on each flank of the base, to test the measure of each section against the others. These tests were satisfactory; for the extreme difference between the measured length of the whole base, and its computed length by triangulation from either section, has been found to be *one inch*. The comparison of the measured length, with the computed value brought down by triangulation from the Calcutta Base line is singularly satisfactory, for the error of the computed value is only *one quarter of an inch,* though the triangulation embraces a distance of four hundred and eighty miles, much of it passing over flat plains which are covered with dense forest and jungle, and very difficult to work through.

On the completion of the Base line, Captain Branfill was deputed to connect it with the principal triangles of the Coast series, and to execute the verificatory triangulation between the sections. Meanwhile, Captain Basevi proceeded, by my instructions, to make a reconnoisance of the neighbouring territories of the Rajah of Jeypore.

It is a singular fact that, in the vicinity of the British stations of Vizagapatam and Vizianagram, and within sixty miles of a coast which has been frequented by British traders for upwards of a century, there is an extensive tract of country, subject to a friendly Rajah, of which less is known, than of districts occupied by hostile tribes along the frontier of our recently acquired Punjab Provinces. A glance at any map of the Madras Presidency reveals a great blank in our geographical knowledge, in the tract of country which lies parallel to the coast, and N.E. of the Godavery river. Its deadly reputation appears to have been a bar alike to the explorations of the curious and scientific, and to the visits of sportsmen. No regular survey of it has ever been attempted; the few places given in the map seem to have been obtained from native information, for they are generally exceedingly erroneous.

A reconnoisance of this tract was required for our own operations, in the extension of the Bombay Longitudinal series to Vizagapatam. As any reliable information regarding land so little known might be expected to be of much value and general interest, I was much gratified when Captain Basevi volunteered to reconnoitre this *terra incognita ;* though, at the sametime, I could not but feel apprehensive for his safety in a country so deadly, for his route would have to pass through dense jungle, in which it would be necessary for him to preserve his reckoning by the troublesome process of traversing, which, under such circumstances, is very laborious, and entails the necessity of performing the greater part of each day's march on foot. The inevitable exposure to be thus undergone is very great, in a tropical climate, and when the district to be traversed is known to be exceedingly feverish and unhealthy, no small amount of courage is needed, to prompt a man to volunteer for such a task.

Captain Basevi took with him one European Assistant, Mr. O'Neill, and a few natives. He himself, fortunately escaped with a slight attack of fever, but Mr. O'Neill suffered severely, and has not yet recovered, and the natives of the party were also, more or less incapacitated by fever, so that but for the assistance afforded by the Rajah of Jeypore, the operations would have been stopped almost at their very commencement. The results are, a good preliminary map of Jeypore, which has been forwarded to the Surveyor General, to be lithographed and published; a report by Captain Basevi, giving details of his route, and a general description of the country; several valuable astronomical determinations of latitudes and longitudes, and barometrical determinations of heights; also memoranda of various other routes, the details of which were obtained from native information. In consideration of the great value of Captain Basevi's services, he has been permitted to proceed to Europe on furlough for one year, during which his appointment will be kept open for him.

During the summer of 1862, the field season of the Kashmir survey party, the triangulation made great progress to the east of Léh, and stations were fixed on the Chinese frontier, from which a number of peaks in Tartary were determined. Some of these were more than one hundred miles distant, and will materially aid in the construction, from native information, of maps of districts into which the surveyors will probably be unable to penetrate. Several of the stations observed from, were over 20,000 feet in height above the sea, and Mr. Johnson visited one peak of a height of no less than 21,072 feet, but, owing to a very heavy fall of snow, was unable to observe from it.

A great many points were fixed in the Pangkong district. The whole of Astor was triangulated, and several peaks were fixed to the north of Gilgit; none of these were of any great height, the highest being only a little over 19,000 feet. The natural difficulties of the country were at first much enhanced by bad weather, which came on with the heavy rains in the southern and outer Himalayan range. Notwithstanding these circumstances the out-turn of work has been good, and the general progress very satisfactory, the total area of the triangulation being about 10,500 square miles, and of topography 10,400 square miles, on the scale of four miles to the inch.

The Topographical operations made good progress, though not so great as would have been the case had all the assistants retained their health. Unfortunately two of them, on entering the higher ranges, broke down completely, and a third had to leave off work early in the season. The ground sketched was generally very elevated and barren, the surveyors' chief difficulties arising from the want of provisions and firewood, and sometimes even of fresh water. The plane table sketches required for the map of Little Tibet have been completed, and lodged in the head-quarters office at Dehra. A glacier, about twenty miles in length, was discovered by Mr. Ryall at the head of the Nubra Valley. Some large glaciers were also found in the neighbourhood of the Nanga Parbat.

I fully concur in the testimony which is borne by Captain Montgomerie, to the great zeal with which these arduous survey operations have been carried on by all the assistants under his orders. The good fortune of success has hitherto attended all undertakings executed under the superintendence of this officer.

There is much reason to expect that, if the snows are not unusually heavy, and if most of the surveyors keep in good health, the remainder of the country to be surveyed in and around Kashmir and Ladak, will be completed during the next field season. Captain Montgomerie has made every effort to persuade the Maharajah of Kashmir to allow one of our surveyors to go to Gilgit, and has obtained a half promise to this effect. Possibly the fear of being called to account, should any harm happen to a European in his territories, causes the Maharajah to hesitate to sanction an undertaking which might be somewhat perilous. He informed Captain Montgomerie that, during the late winter, his troops in Gilgit had been sleeping: no exacter information could be elicited than what is suggested by this metaphor. If, as Captain Montgomerie thinks likely, the sleep was that which knows no waking, the Sikh garrison of Maharajah must have been massacred by the hill tribes, in which case there is little hope of our surveyors being soon able to penetrate into Gilgit.

The eastern frontier party, under the charge of Mr. C. Lane, Chief Civil Assistant, has been employed, throughout the field season, in Independent Tipperah. At the end of the preceding season, this triangulation had reached a point to the south of Cherra Poonjee, on the confines of Tipperah, where the British boundary retrogrades westward to a considerable distance, so that the triangulation would have had to make an extensive circuit, in its onward progress to Chittagong, had the operations been required to be kept within the British boundary. Fortunately, Mr. Buckland, the Commissioner of Chittagong, had sufficient influence with the Maharajah of Tipperah to induce him to consent to our operations being carried across his territory, on the direct line to Chittagong.

Mr. Lane proceeded, in the first instance, to Agartolla, the chief town of Tipperah, where the Maharajah resides; and there he succeeded in securing the friendship and good-will of the prince and his court to an extent to justify the expectation, which was subsequently realized, of obtaining their cordial assistance and co-operation. Mr. Lane deserves much credit for the tact he has displayed in cultivating amicable relations with the barbarous races that inhabit the hill country of Tipperah, who have long been a terror to the industrious population of the plains within the British frontier. Mr. Lane has sent a valuable report on the portion of Independent Tipperah traversed by himself and assistants during the past field season.

The east Calcutta longitudinal series party was formed on the 1st September, 1862, and placed under the charge of Lieutenant Thuillier. The object of this series is to become the basis for the surveys of the districts of Nuddéah, Jessore, and on, *viâ* Dacca, to the eastern frontier along a parallel of latitude slighty north of Calcutta. The publication of the sheets of the Indian Atlas, which embrace these districts has long been delayed for want of this triangulation.

The party proceeded from Dehra Doon, by steamer and railway, to

Calcutta, where they took the field in November on the termination of the rainy season. Operations were commenced at Chinsura, on a side of the Calcutta meridional series. Much assistance was derived from a carefully executed Map, prepared in the Surveyor General's Office, by which Lieutenant Thuillier was enabled to lay out his lines so as to pass through a minimum amount of property. In working through forests and jungle, it is usual, in the first instance, to cut a narrow glade, in a perfectly straight line, through all intermediate obstacles, in the direction of the required station; when this trial line has been carried over a distance of eight to ten miles, the ground beyond is carefully reconnoitered for a suitable site, to which a line is cut from a convenient point in the trial line; thus two sides and the included angle of a triangle are given, with which data it is easy to ascertain the direct line between the two stations, which is then cleared to obtain mutual visibility. Owing, however, to the valuable nature of the property through which the triangles were carried, it was necessary to run a traverse along each line, with numerous intermediate bends, to avoid houses and orchards. In clearing the final line, great caution was requisite to prevent any tree from being cut down needlessly, a matter of some importance in Bengal, where every tree is more or less valuable, and has to be paid for. These circumstances greatly increased the labor of the preliminary operations, and protracted them over a longer period than is usual.

Further delay was caused in building the principal stations. These are usually, towers, with a central pillar, four feet in diameter, of burnt brick and lime masonry, surrounded by a platform of unburnt bricks and mud, fourteen to sixteen feet square, the whole raised to a height of twenty to forty feet, according to the nature of the obstacles to be overlooked. This structure has been adopted on account of its cheapness, and the rapidity with which it can be constructed; it has hitherto been found to be well adapted to our requirements. But it appears to be inapplicable to the rainy and moist climate of eastern Bengal, where unburnt bricks rarely have an opportunity of drying sufficiently to be safely used, in raising a structure of such necessarily large dimensions. At one of Lieutenant Thuillier's stations, in consequence of the employment of damp materials in the unburnt brick-work, and constant and heavy falls of rain during the construction, the building gave way under the weight of the instruments and observatory tent. Fortunately, the large theodolite was packed in its case, and received no injury, but the season was too far advanced for the tower to be rebuilt before the setting in of the monsoon, and as the mishap occurred in the first polygon of the principal triangulation, and there were no more towers ready in advance, the out-turn of work, as measured by the area triangulated, is unusually small, though much valuable experience has been gained, and there is every reason to hope that there will be a full out-turn of work next season. The design of the tower stations will have to be altered to suit the climate of eastern Bengal; in lieu of the present solid mass of earthwork, it will be necessary to build a masonry wall around the central pillar, to support the observer's platform.

The Rahoon meridional series, under the superintendence of Mr. H. Keelan, First Assistant G. T. Survey, was brought to a termination during the last field season, by being extended southwards until it joined the Great Longitudinal Series of Triangles, connecting Calcutta and Karachi. The meridional distance triangulated is sixty-nine miles, by thirteen principal triangles, arranged in polygons, for mutual verification, and covering an area of 1,603 square miles.

This series has taken six years to accomplish. It was commenced by Mr. Logan, late first Assistant G. T. Survey, but has been chiefly executed by Mr. Keelan. It is double throughout, the triangles being arranged in successive quadrilaterals and polygons of remarkable symmetry. Its meridional length is 457 miles; the principal and secondary triangles cover an area of 23,620 square miles. The computations and maps connected therewith will be completed by the 1st October, when the party will be transferred to the districts on the meridian of 84°, between Sumbulpoor and the east coast. The total cost of the operations, up to 1st October, will be about rupees 2,01,600, which gives a rate of rupees 8-8-6, or about 17 shillings per square mile.

The field operations of the Gurhagurh series, on the meridian of Umritsur, were brought to a termination at the end of season 1861-62, when it formed a junction with the series of triangles on the same meridian which had been brought up by Captain Rivers as far as Ajmere, from the Great Longitudinal series. By the 1st October, 1862, the recess computations and charts were completed, and the party was available for transfer elsewhere. This series has taken five years to complete; the greater portion has been executed by Mr. George Shelverton. Its meridional length is 557 miles; the area covered by the principal and secondary triangles, 19,096 square miles; the cost, rupees 1,08,212, which gives a rate of rupees 5-10-8, or about 11 shillings per square mile.

The Sutlej series follows the left bank of the Sutlej from its junction with the Indus, near Mithunkote, to a side of the Gurhagurh series, near Ferozepoor. It was commenced towards the close of field season 1860-61, by Lieutenant Herschel, and was completed last season by Mr. Shelverton. It is single throughout. The recess computations will be completed by 1st October, when the party will be transferred to the meridian of 80°, to execute the required triangulation between Jubbulpoor and Madras. During the past field season the triangulation extended over a distance of 112 miles, covering an area of 1,366 square miles. A very creditable amount of secondary triangulation was also executed. The total cost of the series, up to 1st October, the date of its completion, will be about rupees 80,743; the total area covered by the triangulation is 8,142 square miles, thus giving a rate of rupees 9-14-8, or nearly 20 shillings per mile.

The Bombay party, under the superintendence of Captain Haig, Royal (Bombay) Engineers, having completed the triangulation in northern Bombay, was deputed to execute a series of triangles to the south of the parallel of Bombay, on the meridian of Mangalore. While the preliminary operations and selection of stations were proceeding, Captain Haig marched to the origin of the Bombay longitudinal series, with a view to making this series double throughout, by adding flank stations, so as to form polygons in parts where there were only single triangles. On reaching the ground, it was found that the ends of the Beder Base line were, fortunately, in good preservation. Three of the advanced stations had, however, been completely destroyed. Captain Haig judiciously determined to triangulate the series anew, as far west as the Mangalore meridian. The revision having been executed with a a much superior instrument to that employed in the original triangulation, the value of this portion of the Bombay Longitudinal series is very greatly enhanced.

Having completed this revision, Captain Haig was proceeding with the principal triangulation on the meridian of Mangalore, when an untoward accident brought his operations to an abrupt termination. The large theodolite was set up for observation on the tower station of Palwan, when, without any previous warning, the tower gave way on one side, causing the fall of the instrument and observatory tent, whereby the instrument was so seriously injured that it is incapable of being again used, until it has been repaired by the makers in England. Fortunately, the horizontal circle, the most valuable portion, appears to have escaped injury, but the vertical circle was destroyed, and the injuries are such that the instrument cannot be repaired in this country. Capt. Haig convened a Court of Enquiry to report on the circumstances; the proceedings of the Court have already been submitted to Government. The Court came to the opinion, in which I entirely concur, that the fall of the tower was occasioned by the sudden and unexpected sinking of the ground below, and that no blame is attributable to Captain Haig or any other person, for the mishap.

Captain Haig had already turned out a very excellent season's work, comprising thirty-two principal triangles, covering an area of 6,625 square miles, and extending over a length of 260 miles, whereof 66 appertain to the Mangalore meridian, and 194 to the parallel of Bombay.

The Spirit Levelling operations were carried on by Mr. Donnelly, Civil Second Assistant, under the superintendence of Lieutenant Thuillier. The party accompanied me to Calcutta, to receive the necessary instructions regarding the programme of the season's operations, which could not be decided on until I had obtained reliable information regarding the Railway levels between Calcutta and Agra. I had hoped to be able to incorporate these into our work, so as to avoid the labor and expense of carrying a line of levels all that distance. During the previous field season, a connection had been made, at Agra, with the Railway levels brought up from Calcutta, and the G. T. Survey levels, brought up from the mean sea level at Karachi. The two sets of results differed by about twenty-four feet, and it was hoped that all difference would disappear, on connecting the Railway datum, the site of Howrah Dock, with the mean sea level of the Bay of Bengal.

That level had already been closely ascertained, by a series of tidal observations taken at Kydd's Dock, and subsequently verified by others taken at Kejiri, from the description of which (*vide* foot-notes) it is evident that the mean sea level of the Bay of Bengal may be considered to be known, to within a few inches of the truth.* On connecting the

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* The following description of the connection of Kydd's Dock with the mean sea level of the Bay of Bengal is taken from a Report, dated 1st November, 1854, on the Calcutta Meridional Series, by Colonel Waugh, Surveyor-General, and Superintendent G. T. S. :—

" A register of the tides in the river Hoogly is regularly kept at Kydd's Dockyard, near Calcutta, the height of each successive tide being referred to a fixed datum line or zero which is the bottom or sill stone of the dock, and therefore an object of invariable character.

" A transcript of the register of the tides for two years, viz., from May, 1846, to April 1848, having been obtained from the Marine Department, a monthly abstract of mean tide was deduced therefrom.

" The waters of the ocean would maintain a constant level if undisturbed by the action of the sun and moon. La Place has demonstrated that this level is a mean between the highest and lowest state to which the surface of the ocean is reduced by the attraction of those bodies. This mathematical truth is corroborated by observations made on open coasts, from which it results that the mean of high and low water for two consecutive tides represents, very nearly, the level of the sea, and that the average for a lunation is constant within a very small quantity.,"—*Vide* Professor Whewell's Report, Vol. VII., British Association's Report.

" An examination of the abstract of monthly mean tides will, however, show that considerable irregularity exists in the river Hoogly, the monthly means differing as much as six and a half feet. Now if the annual average be considered as the true level of the sea, it would follow that for some months, consecutively, the mean height of the river is two and a half feet below the sea level, a conclusion which is altogether inadmissible.

" The lowest monthly mean tide occurs about February and March, when the fresh water in the river is lowest, and strong Southerly winds do not prevail. The mean tide rises gradually, as the river rises during the south monsoon, until it attains its maximum in September or October, at which time the monthly mean exceeds that of February by no less than six feet. This rise is, obviously, the effect of accumulation, produced by inundation in the Valley of the Ganges, and the force of the S.W. wind, which dams up the freshes in the long and narrow channel of the river.

" It has been remarked by Colonel Cheape, Chief Engineer, in his memoirs, dated April, 1825, that the surface of the Salt Water Lake, wherein the rise of the tide is almost imperceptible, would on account of its wide expanse, represent very accurately the level of the sea with which it communicates. He also observes that Captain Taylor's levels indicate that the surface of the lake in the dry season is 2 feet 4 3 inches below the mean state of the river. This result corresponds very nearly with the mean tide of the river itself, which in February is 2 feet 5 inches below the level of the annual mean.

" Colonel Cheape further states that the periodic rise of the surface of the lake in the wet season is ten inches. Now, the contemporaneous rise in the mean tide of the river has been shown to be six feet, and as the cause of these elevations is precisely the same, though the effects are in the ratio seven to one, the greater rise in the river can clearly be attributed only to the narrowness of its channel compared with the bay : it is probable that a considerable portion of the rise of ten inches in the surface of the lake is also due to accumulation ; so that, although a rise may be supposed to take place in the level of the sea at the head of the bay, during the continued pressure of the S.W. monsoon, still, that elevation must be much less than what takes place in the lake, where the effect of this rise is increased by the narrowness of the channel, and the influx of fresh water during the inundation.

" It has been shown, that if the annual average of mean water be taken as the sea level, it would lead to the inadmissible conclusion that in the dry season, the average level of the river at Calcutta is twenty-nine inches below the sea, with which it freely communicates. It has also been shown that the surface of the great Salt Water Lake, in the dry season, is on a level, or nearly so, with the mean tide of the river at the same time. It is likewise manifest that the periodic rise of mean tide during he monsoon, to the extent of six feet in the river and ten inches in the lake is occasioned by local causes, independent altogether of the true level of the sea, which is a constant level, and these causes, i appears, operating in narrow channels are capable of producing exaggerated results in the proportion of seven to one, showing clearly the fact of accumulation. Hence the conclusion is inevitable, that the lowest monthly mean tide of the river, observed in February and March, represents the nearest approximation to the actual sea level, and that the rise of mean tide at Calcutta during other months may fairly be ascribed to disturbing causes of an inland character, altogether independent of the true and constant level of the ocean. The variable character of the disturbing causes is shown by

Railway levels with Kydd's Dock, it was found that there still remained the fact that the monthly means of corresponding months, for the two years differ considerably, except in the months of February and March, the monthly mean tides of which are very accordant.

"Proceeding upon this principle, I have used the following observations to refer the datum line in Kydd's Dock to the sea level :—

Mean tide	February, 1847,	above datum as measured on guage,			...	... 8·11 feet.
„	March, „	„	„	„	...	... 8·45 „
„	February, 1848,	„	„	„	...	... 8·48 „
„	March, „	„	„	„	...	... 8·50 „
„	February, 1850,	„	„	„	...	... 8·28 „
„	March, „	„	„	„	...	... 8·62 „
„	February, 1851,	„	„	„	...	... 7·94 „
„	March, „	„	„	„	...	... 8·36 „
				Mean,	...	... 8·343 feet

"Correction for error of graduation on gauge by Mr. Bedford's measurements, 0·576 feet.

"By tides measured at Calcutta in February and March, mean sea level above datum, ... 8·576 feet.

"Again, in the years 1850 and 1851, Mr. Bedford, the Marine Surveyor, took a series of tidal observations at Kejiri, and connecting this point by a series of levels with Kydd's Dock, found the datum line at the latter point is 9·07 feet below the sea level. Mr. Bedford's observations, from which this result is derived, are as follows :—

MEAN LEVELS OF THE RIVER'S MOUTH AT KEJIRI, AT NEAP TIDES, FOR THE YEARS 1850 AND 1851, EXCLUDING THE SOUTH-WEST MONSOON.

Months.	Highest Low Water.		Lowest High Water.		Mean.	
	Feet.	*Inches.*	*Feet.*	*Inches.*	*Feet.*	*Inches.*
1850.						
January, ...	5	0	11	9	8	4½
	4	0	11	9	7	10½
February, ...	5	6	11	0	8	3
	4	9	11	6	8	1½
March, ...	6	0	11	0	8	0
	4	9	12	0	8	4½
April, ...	6	9	11	0	8	10½
	4	9	12	6	8	7½
May, ...	6	9	12	0	9	4½
	5	3	13	0	9	1½
June, ...	6	6	13	3	9	10½
	6	0	14	9	10	4½
November, ...	7	0	13	3	9	7½
	4	9	13	0	8	10½
December, ...	5	9	11	9	8	9
	4	6	12	3	9	4½
1851.						
January, ...	4	6	11	9	8	1½
	4	3	11	0	7	7½
February, ...	4	3	11	3	7	9
	5	0	10	3	7	7½
March, ...	4	9	11	0	7	10½
	6	3	11	9	9	0
April, ...	5	3	12	9	9	0
	7	0	10	6	8	9
May, ...	5	6	12	6	9	1½
	7	0	12	9	9	9
June, ...	6	0	14	6	10	3
	6	9	13	3	10	0

a difference of about twelve feet between the Railway and the Survey height of Agra.* On discussing this subject with the Chief Engineer of the Railway, I ascertained that there were several breaks in the Railway

			feet.	inches.
" Mean height of sea level above the datum line at Kejiri,	...	...	8	9·75
" Datum line at Kejiri above that of Kydd's guage,	...	...	0	2·88
" Sea level above the datum line of Kydd's guage,	...	...	9	0·63
" Which reduced to decimals of a foot, becomes, ...	...	...		9·053

" Which differs from my determination by half a foot; but, if the tides at Kejiri for February and March be alone taken into account, at which period the inland waters flowing seaward are lowest, the result would agree with that derived from my discussion of the tides at Calcutta to about one inch."

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* Mr. Donnelly reports that he was much delayed by the discrepancies which were found between his levels and those of the Railway. They entailed the re-measurement of two sections, one fifteen, the other twenty-six miles in length. In the first, the discrepancy was five feet; in the second seventeen and a-half feet. Mr. Donnelly and his Assistant re-measured both these sections, and obtained results differing from their first results by only ·032 of a foot in the first instance, and ·043 in the second, clearly shewing that the error did not lie in their work.

In the course of the Field Season, Mr. Donnelly laid down nine G. T. S. Bench-marks, fixed two G. T. S. Trigonometrical Stations, and connected one hundred and forty-one points, principally Railway mile-stones, Bridges, Bench marks, and Station Platforms.

COMPARISON OF RAILWAY AND G T. SURVEY LEVELLED HEIGHTS.

Names of Railway Stations and Bench-marks.	G. T. Survey.		Railway.	G. T. S. — Railway.	Remarks.
	Height above Mean Sea Level	Height above Howrah Dock Sill.	Height above Howrah Dock Sill.		
Serampoor, ...	+ 20·910	+ 32·552	+ 32·230	+ 0·322	Level of Rails.
Pundooa, ...	+ 42·398	+ 54·031	+ 54·140	+ 0·100	Do.
Dymaree, ...	+ 66·691	+ 78·339	+ 78·260	+ 5·079	Do.
Burdwan, ...	+ 100·325	+ 111·958	+ 107·260	+ 4·698	Do.
Kanoo Junction, ...	+ 121·439	+ 133·172	+ 128·250	+ 4·922	Do.
Gooskarrah, ...	+ 110·918	+ 122·137	+ 118·250	+ 3·887	Do.
Beddiah, ...	+ 132·270	+ 143·903	+ 140·250	+ 5·663	Do.
Bulpoor,...	+ 166·635	+ 171·268	+ 167·250	+ 4·018	Do.
Ahmadpoor, ...	+ 134·213	+ 145·846	+ 142·250	+ 3·596	Do.
Cynthea, ...	+ 168·330	+ 179·963	+ 176·250	+ 3·713	Do.
Dullarpoor, ...	+ 143·709	+ 155·362	+ 151·230	+ 4·112	N. W. Plinth of Station-house.
Rampoor Haut, B. D.,	+ 116·810	+ 128·143	+ 124·960	+ 3·483	Square Pillar in centre of Line, opposite Booking-office.
Pakowr,...	+ 104·392	+ 116·025	+ 112·250	+ 3·775	Level of Rails.
Teenpahar, ...	+ 103·770	+ 115 422	+ 129·250	— 13·838	Do.
Tilliaghuree, B. D., ...	+ 110·900	+ 122·583	+ 135·830	- 11·806	Square Pillar on Line to E., marked D.
Do.	+ 96·638	+ 108·271	+ 121·090	- 12·809	Heel Stone of Gateway, W. Gate of Fort N. side, original B. D.

levels, that, in consequence of the pressure of other work, there had been no opportunity of preparing a correct and true section of the whole line, and that it was contemplated to re-level the line, as soon as the Engineers had leisure to do so. I decided, therefore, on deputing the levelling party to re-level the line of the Railway, and connect all the Trigonometrical Stations within reach thereof.

Mr. Donnelly made good progress, and accomplished two hundred and forty-two miles of first-class levelling,* forty-one of which had to be re-levelled, on account of large discrepancies which were found in the Railway levels. The operations had reached the vicinity of Bhagulpore, when Mr. Donnelly was compelled, by severe illness, to close work.

During the year under review, I was called upon to collect all the available data of levels, existing in the Public Works, Railway, and Survey Offices, all over India, in order to reduce them to a common datum. As a first step towards this desirable measure, I have published a volume of Tables of Levels, based on the Spirit-Levelling operations of this Survey, and reduced to the mean sea level of Karachi harbour, as their datum. Additional volumes will be published as soon as possible. They will enable Officers of the Public Works and Railway Departments to reduce their levels to the mean sea, by connecting them with the nearest Bench-mark, or Station of the Trigonometrical Survey. In most instances, however, the business of connecting will probably devolve on the Survey Department. At present, we have only one Levelling party, which is employed in Bengal; I therefore submitted a project for the formation of other parties, to carry on operations, simultaneously, in the Madras and Bombay Presidencies, as the only means of speedily accomplishing an operation, of which the practical value will be greatly enhanced by early completion. Unfortunately, financial reasons have interfered to prevent this proposal from being sanctioned.

I now proceed to report on the Astronomical Observations for the determinations of the Latitude and Longitude of the Andaman Islands, which were instituted on a representation by the Superintendent of Port Blair, that the erroneous positions assigned to some of these

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* With an Assistant levelling the line, independently, behind him, station by station, after the method described in the published volume of Tables of Heights.

Islands, in the published Charts, endangered the safety of ships sailing between Calcutta and Singapore. Under the orders of Government in the Home Department, the Surveyor General had deputed a Surveyor, Mr. Nicolson, to conduct the necessary observations, the superintendence of which was subsequently transferred to the Trigonometrical branch of the Survey.

Mr. Nicolson started from Calcutta early in December, 1861, to reconnoitre the Coco and Andaman Islands. He found that, in order to take a complete Series of Astronomical Observations at the Great Coco, it would be necessary to have a steamer placed at his disposal for some weeks, to keep up his communication with Port Blair, and bring the necessary supplies for his party.

About this time, a communication was received from the Bombay Government, representing that there was as much doubt about the accuracy of the position of Port Blair, as of that of the Coco Islands. Under these circumstances, it seemed advisable that Mr. Nicolson should begin operations by fixing Port Blair, in order that the proposed operations might be commenced at the place where the greatest facilities for their execution existed.

The inaccuracy of the present Charts of the islands lying between Sumatra and Burma being admitted on all sides, it appeared necessary, in the absence of any regular survey of those islands to fix, by astronomical observations, the positions of Acheen Head, Port Blair, the Great Coco, or the Preparis Island, and an island in each of the other groups intermediate between Acheen Head and Cape Negrais. It is believed that the relative positions of the mutually visible islands of each group are already correctly shown on the Charts; consequently, by determining the absolute position of a point in each group, it would be possible to rectify the existing Charts, without making a general re-survey.

Mr. Nicolson, having completed his reconnoissance, returned to Calcutta in February, 1862, by which time one of the large 3-foot astronomical circles of the Trigonometrical Survey had been got ready, and a portable observatory, with rotating dome, constructed for the observations. There was no good astronomical telescope available in the stores of the Mathematical Instrument Department; consequently, Mr. Nicolson was directed to take all his observations, whether of occultations, eclipses, or moon culminations, with the telescope of the astronomical circle, which he could point to any part of the sky, through the aperture in the rotating dome of the observatory. Owing, however, to the small number of occultations and culminations which occur monthly, and the risk of losing some of them in cloudy weather, Mr. Nicolson was directed to base his observations for Longitude chiefly on the measurement of lunar zenith distances, for which the astronomical circle is well adapted. He was supplied with an astronomical clock, and all other necessary instruments, from the Calcutta Observatory.

In May, 1862, Mr. Nicolson had set up his observatory at Port Blair, and was ready to commence observations. Unfortunately, the season of fine weather had then nearly terminated; the monsoon set in with unusual severity, nights favorable for observing were few and far between, and, consequently, several months elapsed before the whole of the necessary observations for Latitude and Longitude were completed. The work was further impeded by the delays attendant on postal communication between Calcutta and Port Blair, making it very difficult for me to exercise that degree of supervision over the operations, which their delicate and difficult nature required.

By the end of 1862, Mr. Nicolson reported that he had taken a sufficient number of observations to fix the position of Port Blair; he, therefore, applied for a vessel to be placed at his disposal to enable him to proceed to fix the positions of the Great Coco, and other islands. Owing to postal and other delays, it was not until the end of February, 1863, on my return from Vizagapatam, that I learnt from the Marine Department that no vessel was available, nor could one be got ready before the fine weather season would have terminated.

From the same communication I also learnt that the Secretary of State for India had ordered a complete Maritime Survey of the Andaman Islands to be executed. Being then in Calcutta, I went to Captain Rennie, the Secretary to Government of India, Marine Department, and was informed that, under instructions from the Admiralty Hydrographer, it had been determined to find the differences of Longitude between the various groups of islands, chronometrically, by a battery of thirteen or fourteen chronometers.

The circumstances under which it was originally proposed to fix a series of positions by astronomical observations had thus entirely altered. The complete Maritime Survey, which has been ordered by the Right Hon. the Secretary of State for India, renders further astronomical observations unnecessary. The determinations of differences of Longitude, which are the only really difficult portion of the work, can be done chronometrically by the Marine Surveyors, with much greater rapidity and economy, and, probably even with greater accuracy, than by the best astronomical observations for absolute Longitude.

Consequently, in March last, I desired Mr. Nicolson to restrict his operations to taking as many more observations for the determination of the Longitude of Port Blair, as could be obtained before the setting in of the monsoon, and then to return to Calcutta. He reached the Presidency in June, and has ever since been employed in reducing his observations. They consist of 32 lunar culminations, 136 lunar zenith distances, 130 transits of clock stars, and 162 meridional zenith distances of stars for Latitude, observed up to the 12th March, when the astronomical clock met with an accident, and Mr. Nicolson was afterwards obliged to employ a chronometer. His subsequent observations are, consequently, not as valuable as the earlier ones; they consist of 9 culminations, 64 lunar zenith distances, and 36 clock stars. The whole of the Latitude observations have been reduced, and found exceedingly satisfactory. There has not yet been leisure to reduce more than a few of the observations for Longitude, but the results obtained hitherto are satisfactory. The final resulting Longitude will be communicated for publication in the *Calcutta Gazette* as soon as ascertained. It should serve as an excellent datum for the proposed Maritime Surveys, and save the expense of a series of voyages between Madras and Port Blair, which would otherwise have to be incurred to obtain a good chronometric determination of the Longitude of Port Blair.

THE OUT-TURN OF WORK EXECUTED BY EACH PARTY DURING THE FIELD OPERATIONS OF THE OFFICIAL YEAR 1862-63, IS SHOWN IN THE FOLLOWING ABSTRACT:—

STATISTICS.	Kashmir Series.	Coast Series.	Sutlej Series.	East Calcutta Longtdal. Series.	Rahoon Meridional Series.	Eastern Frontier Series.	Bombay Party.	Total Out-turn of Work.
Principal Triangles, ...	...	19	29	4	13	16	32	113
Average error of Principal Triangles in seconds, ...	...	0″.94	0″.43	0″.44	0″.46	0″.43	0″.89	0″.65 average.
Observed Azimuths,.	...	1	1	...	2	...	1	5
Secondary Triangles with all three Angles Observed, ...	...	10	132	...	16	...	32	190
Area of Principal Triangulation, square miles, ... , .	...	256	1,366	220	1,603	884	6,625	10,954
Area of Secondary Triangulation, square miles, ...	10,500	...	4,816	...	950	263	1,510	18,139
Area of Topographically Surveyed, scale 4 miles = 1 inch, square miles, . .	10,400	...	...	...	...	...	...	10,400
Intersected Points, ...	...	12	112	...	18	22	110	274
Length of Principal Triangulation in miles,	...	...	112	20	69	49	260	490
„ Secondary „	...	...	340	...	72	...	100	512
Miles of rays cleared between Principal Stations, ...	...	...	300	253	159	...	...	712
Towers built for Principal Stations,. .	...	...	11	5	5	...	2	23
Platforms „ . .	...	12	...	...	6	17	44	79
Platforms built for Secondary Stations, .	...	...	95	...	...	...	...	95
Length of Triangulation laid out in advance in miles, ...	...	...	...	45	...	77	150	272
Principal Stations selected in advance, .	...	...	...	8	...	17	36	61

The Computing Office has been employed in a variety of preliminary operations, which are necessary to form the basis of a general reduction of the whole of the principal triangulation of this Survey, which will shortly become necessary, now that almost the whole of the triangulation of the tracts of country comprised in the great quadrilateral figure connecting Calcutta, Karachi, Attok, and Purnea, is completed. Though the triangulation has been executed with the very best instruments, and though the system of observation which was introduced into this Department by Colonel Everest, is more rigorous and accurate than that of any European Survey, it is evident that, in consequence of the vast length of each Series, and the imperfections which necessarily attend whatever is the work of human hands, each Series generates a certain amount of error, which becomes apparent as linear error on the termination of the Series on a measured Base line, while on the close of a circuit formed by two Meridional Series, and the portions of the connecting Longitudinal Series at their extremities, it produces errors of Latitude, Longitude, and Azimuth. The dispersion of these errors in such a manner as to obtain the most probable results of the whole, giving its due weight to each fact of observation, and taking into consideration the bearing of every such fact on all the rest, is a matter of great intricacy and difficulty, on which it will be necessary for me to consult with the ablest mathematicians of the present day in Europe, before deciding on the system to be finally adopted. Meanwhile, the necessary preliminaries for the eventual calculations are being carefully elaborated by Lieutenant Herschel, to whom I am indebted for numerous very valuable suggestions, and for co-operation as cordial as it has been unintermittent.

While the practical operations of this department may be confidently pronounced to be of a superior order to similar operations in any other part of the globe, it must, on the other hand, be admitted, that the theoretical applications, for the reduction of the triangulation, have not kept pace with recent improvements in geodetical science, which have been introduced into some European Surveys. The method which has hitherto been employed for reducing the observed angles, so as to satisfy all the equations of condition of each figure, though a great improvement on any previous method, has had, in its turn, to give way to the subsequently discovered method of minimum squares. The algebraical solution of the equations necessary to satisfy the condition that the sum of the squares of the errors shall be a minimum, is by no means difficult, but hitherto there has been no practical adaptation of it in this Survey, chiefly owing to the pressure of other and more urgent business, on those alone capable of dealing with the subject. Much progress has, however, been recently made in this direction, and I am indebted to Lieutenant Herschel for devising methods of calculation, which will enable the reduction of our figures to be effected, according to the new and rigorous system, by native computers possessing little more than a knowledge of arithmetic, with even greater facility than the less refined methods of reduction, which have hitherto been employed.

The Drawing Office has been chiefly employed in compiling Maps of the dominions subject to the Maharajah of Kashmir, from the plane table sheets sent in by Captain Montgomerie. A new Chart of the Triangulation of this Survey, up to date, has also been prepared, and a Chart to illustrate the volume of Tables of Heights recently published; both these Charts were lithographed in the Office of the Surveyor General, Calcutta. Nine original preliminary Charts of the triangulation, in various parts of India, have been prepared, in duplicate, for the use of the Surveyor General's Office, and the Geographer to the Right Hon. the Secretary of State for India. The Photographic apparatus is also being usefully employed in copying and reducing Maps, and in furnishing preliminary copies for current use, until the originals are engraved and published. Owing, however, to the small establishments at my disposal, the photography is necessarily restricted to the short period of the recess of the Kashmir party, three to four months, when the services of our best Photographer, Captain Melville, are available for their management.

In the Instrumental Department, great advantages may be expected by the appointment recently made by the Right Hon. the Secretary of State for India, of an Officer, Colonel Strange, to superintend the construction of the new Great Theodolite, and various astronomical instruments, which are being prepared in England for this Department. When they are received in India, we shall be in a position to undertake the necessary operations for ascertaining our Longitudes, in connection with the Observatory at Greenwich, by means of the Electric Telegraph, which is now brought across from the Mediterranean to India.

J. T. WALKER.

VERNACULAR.

ENGINEERING.

	R.	A.
ABBOTT on BRIDGES, and CAUTLEY on WELL FOUNDATIONS,	0	4
	روپیہ	آنہ
بت صاحب کي کتاب پلون کے بيان مين اور کاتلي صاحب کي کوئونکی بنيادون مين	۰	۴
ACCOUNT of the GANGES CANAL, (Oordoo,)	0	4
ناب نہر گنگ کي اُردو مين	۰	۴
„ „ (Hindee,)	0	4
ناب نہر گنگ کي هندي مين	۰	۴
BLASTING UNDER WATER,	0	4
BOILEAU'S TRAVERSE TABLES,	1	0
يورس تيبل	۱	۰
BUILDING MATERIALS,	0	8
شياء سامان عمارت	۰	۸
CONSTRUCTION of BUILDINGS,	1	0
الہ تعمير عمارت	۱	۰
EARTHWORK,	0	6
الہ متّي کي کھودائي کا	۰	۶
ESTIMATES of BUILDINGS,	0	2
مينہ عمارات	۰	۲
EXAMPLES of ESTIMATES,	0	14
ثال تخمينہ عمارت	۰	۱۴
KHUSRAH FIELD MEASUREMENT,	1	0
سرہ پيمايش	۱	۰
NOTES on ROAD MAKING,	1	0
الہ سڑک بنانے کا	۱	۰
ON THE MODES of DRAWING ARCHES,	0	2
ان نقشہ کھنچنے طرح طرح کي محرابون کا	۰	۲
STRENGTH of MATERIALS,	0	8
شداء عمارت	۰	۸

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	R.	A.
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J. G. Medley, Major, R. E.,
Principal.

Roorkee, *Feb. 1st*, 1864.